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RISK REDUCTION ENGINEERING LABORATORY
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16. ABSTRACT

This report summarizes the results of a Superfund Innovative Technology Evaluation (SITE) demonstration of the CF Systems critical fluid organics extraction system at the New Bedford Harbor, Massachusetts Superfund site. The technology depends on the ability of organic pollutants to solubilize in the process solvent, a liquefied gas. The pollutants treated include polychlorinated biphenyls (PCBs) & polynuclear aromatic hydrocarbons. The report examines the performance of the process in terms of PCB extraction efficiency, variation in process operating conditions, potential health and safety impacts, equipment and handling problems, and projected system economics. Volume I covers process design, field activities, sampling and analytical program, and results and discussion. Volume II contains sampling and analytical reports and operating log data.

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FOREWORD

The Superfund Innovative Technology Evaluation (SITE) program was authorized in the 1986 Superfund amendments. The program is a joint effort between EPA's Office of Research and Development and Office of Solid Waste and Emergency Response. The purpose of the program is to assist the development of hazardous waste treatment technologies necessary to implement new cleanup standards that require greater reliance on permanent remedies. This is accomplished through technology demonstrations that are designed to provide engineering and cost data on selected technologies.

This project consists of an analysis of CF Systems' proprietary organics extraction process. The technology demonstration took place at the New Bedford Harbor Superfund site, where harbor sediments are contaminated with polychlorinated biphenyls and other toxics. The demonstration effort was directed at obtaining information on the performance and cost of the process for use in assessments at other sites. Documentation will consist of two reports. This Technology Evaluation Report describes the field activities and laboratory results. An Applications Analysis will follow and provide an interpretation of the data and conclusions on the results and potential applicability of the technology.

Additional copies of this report may be obtained at no charge from EPA's Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, Ohio 45268, using the EPA document number found on the front cover of the report. Once this supply is exhausted, copies can be purchased from the National Technical Information Service, Ravensworth Bldg., Springfield, VA 22161, (703) 487-4600. Reference copies will be available at EPA libraries in their Hazardous Waste Collection. You can also call the SITE Clearinghouse hotline at 1-800-424-9346 or 382-3000 in Washington, DC to inquire about the availability of other reports.

E. Timothy Oppelt, Director
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ABSTRACT

The SITE Program demonstration of CF Systems' organics extraction technology was conducted to obtain specific operating and cost information that could be used in evaluating the potential applicability of the technology to Superfund sites. The demonstration was conducted concurrently with pilot dredging studies managed by the U.S. Army Corps of Engineers at the New Bedford Harbor Superfund site in Massachusetts. Contaminated sediments were treated by CF Systems' Pit Cleanup Unit (PCU) that used liquefied propane/butane as the extraction solvent. The PCU was a trailer-mounted system with a design capacity of 1.5 gpm (20 bbl/day). CF Systems claimed that the PCU would extract organics from contaminated soils based on solubility of organics in liquefied propane/butane.

The objectives included an evaluation of (1) the unit's performance, (2) system operating conditions, (3) health and safety considerations, and (4) equipment and system materials handling problems. Extensive sampling and analyses were performed showing that polychlorinated biphenyl (PCB) extraction efficiencies of 90 percent were achieved for sediments containing PCBs ranging from 350 to 2,575 ppm. In Test 2, sediments containing 350 ppm were reduced to 40 ppm after 10 passes, or recycles, through the PCU. In Test 3, a 288 ppm feed was reduced to 82 ppm after 3 passes. In Test 4, a 2,575 ppm feed was reduced to 200 ppm after 6 passes. Some operating problems occurred, such as the intermittant retention of solids in system hardware and foaming in the treated sediment collection tanks. These problems did not affect extraction efficiency but could affect operation of a full-scale unit. Corrective measures will be addressed by the developer and EPA. A mass balance established over the entire demonstration showed excellent accountability for 96 percent of the total mass. Operation of the unit did not present any threats to the health and safety of operators or the local community.

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ABBREVIATIONS AND SYMBOLS

amps	amperes
ASTM	American Society for Testing and Materials
bbl/day	barrels per day
BNAs	base/neutral and acid extractable compounds
Cd	cadmium
COE	U.S. Army Corps of Engineers
cP	centipoise
Cr	chromium
CR	column reboiler
Cu	copper
CWA	Clean Water Act
dPa.s	decapascal.seconds
ECD	electron capture detector
EPA	Environmental Protection Agency
EPT	extract product tank
EP Tox	Extraction Procedure Toxicity Test - leach test
F	Fahrenheit
FK	feed kettle
g	grams
GC	gas chromotography
gpd	gallons per day
gpm	gallons per minute
kw-hr	kilowatt hours
lbs	pounds
lb/gal	pounds per gallon
lb/min	pounds per minute
max	maximum
MBAS	methylene blue active substances
mg	milligrams
mg/kg	milligrams per kilogram
min	minimum
ms	mass spectrometry
MSA	method of standard additions
MS/MSD	matrix spike/matrix spike duplicate

ND	not detected
NIOSH	National Institute of Occupational Safety and Health
NR	not reported
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
OVA	organic vapor analyzer
oz	ounces
PAHs	polyaromatic hydrocarbons
Pb	lead
PCBs	polychlorinated biphenyls
PCU	Pit Cleanup Unit
ppm	parts per million
psig	pounds per square inch gauge
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act of 1976
RPD	relative percent difference
RREL	Risk Reduction Engineering Laboratory
RSD	relative standard deviation
SARA	Superfund Amendments and Reauthorization Act of 1986
SBT	still bottoms tank
SITE	Superfund Innovative Technology Evaluation Program
SRC	solvent recovery column
TDS	total dissolved solids
TS	total solids
TSS	total suspended solids
VAC	volts, alternating current
VOAs	volatile organic analytes
Zn	zinc
<	less than

SECTION 1

INTRODUCTION

1.1 BACKGROUND

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), the Environmental Protection Agency's Offices of Research and Development (ORD) and Solid Waste and Emergency Response (OSWER) have established a formal program to accelerate the development, demonstration, and use of new or innovative technologies as alternatives to current containment systems for hazardous wates. This program is called Superfund Innovative Technology Evaluation or SITE.

The major objective of a Demonstration Program is to develop reliable cost and performance information on innovative alternative technologies so that they can be adequately considered in Superfund decision making. Common measurement, monitoring, and evaluation guidelines and protocols were developed by ORD and used to collect the data and information from the demonstration.

CF Systems Corp., developer of an organics extraction technology, was selected to demonstrate their system at the New Bedford Harbor, Massachusetts Superfund site. The system demonstrated was CF Systems' Pit Cleanup Unit (PCU), a trailer-mounted system with a design capacity of 1.5 gpm (20 bbl/day). Successful application of the technology depends on the ability of organic pollutants to solubilize in the process solvent, a liquefied gas. The process used a mixture of liquefied propane and butane, at 240 psi and 69 degrees F, as a solvent for extracting organics from soils. As liquefied solvent was mixed with the waste, organics were extracted into the solvent. The solvent-organics mixture was then decanted from the separated solids and water. The pressure of the solvent-organics mixture was reduced slightly to vaporize the solvent which allowed separation from the organics. The solvent was recovered by the system and compressed to a liquid for reuse.

The site is located on the Acushnet River Estuary north of Buzzard's Bay in the city of New Bedford, Massachusetts, where harbor sediments contain

pollutants discharged to the harbor from various industrial sources. The pollutants include polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons, copper, chromium, zinc, and lead. PCBs present the greatest toxic threat and concentrations as high as 30,000 ppm have been observed. The estimated volumes of harbor sediments containing various concentrations of PCBs are:

PCB Concentration (ppm)	Volume (cubic yards)
0-50	878,000
50-500	236,000
500-5,000	91,000
>5,000	16,000

Samples of harbor sediments were dredged by the U.S. Army Corps of Engineers and stored in 55-gallon drums for use in this demonstration.

1.2 PROGRAM OBJECTIVES

The objectives of this SITE demonstration of the CF Systems organics extraction technology at the New Bedford Superfund site were to evaluate the following:

1. Performance of the process in terms of PCB extraction efficiency and a mass balance.
2. Variations in process operating conditions and possible effects on performance.
3. Potential health and safety impacts resulting from system operation.
4. Equipment and material handling problems.
5. Projected system economics.

1.3 TECHNOLOGY EVALUATION CRITERIA

The following technical criteria were used to evaluate the effectiveness of the CF Systems process for extracting PCBs from New Bedford Harbor sediments:

1. System Performance
   a. Evaluate PCB concentration in sediments before and after treatment.

b. Evaluate PCB extraction efficiency with each pass, or recycle, of sediments through the unit.

c. Evaluate mass balances established for total mass, solids, and PCBs.

2. Operating Conditions

a. Compare operating conditions to operating specifications for flow, temperature, pressure, and physical sediment characteristics of the sediment and assess the effect on extraction rate.

3. Health and Safety Considerations

a. Determine if significant amounts of propane/butane or PCBs are emitted to the air by the process.

b. Determine if staging area soils are contaminated by system spills or malfunctions.

c. Decontaminate the unit with toluene to levels less than 50 ppm in decontamination residues.

4. Equipment and Material Handling Problems

a. Observe equipment and material handling problems that would affect the performance of a full-scale site cleanup.

1.4 DESCRIPTION OF OPERATIONS

Contaminated sediments from five harbor locations were processed by the PCU. The Corps of Engineers dredged sediments from the harbor and stored them in 55-gallon drums for processing by the PCU. Sediments were obtained from locations H-20, H-21, H-22, H-23, and I-11 shown in Figure 4.2. Drummed sediments were sieved to remove particles greater than one-eighth inch that could damage system valves. Water was also added to produce a pumpable slurry. The drummed sediments were blended to provide feedstocks for four tests as follows:

Test No.	Feed Stock
1	A 50-gallon mixture of sediments taken from locations H-20, H-21, and H-23. PCB concentration was 360 ppm.
2	A 50-gallon mixture of sediments taken from locations H-20, H-21, and H-23. PCB concentration was 350 ppm.
3	A 50-gallon mixture of sediments taken from locations H-20, H-21, and H-23. PCB concentration was 288 ppm.

4 A 50-gallon mixture of sediments taken from locations H-22 and I-11. PCB concentration was 2,575 ppm.

Test 1 was a system shakedown run to set flow rates and operating pressures and to provide samples for laboratory evaluation of sample matrices. Samples were collected during Tests 2, 3, and 4 to provide data for evaluating the system's performance. A fifth test was run with toluene used as a feedstock for decontaminating the PCU.

The process steps included extraction, phase separation and solvent recovery. A simplified flowchart is shown in Figure 1.1. In step one, sediments were fed into the top of an extractor at a rate of 0.9 gpm. In step two, solvent was compressed to a liquid state and allowed to flow through the same extractor. In the extractor, the solvent was thoroughly mixed with the waste at a pressure of 240 psig. Following this extraction procedure, the residual mixture of water/solids was removed from the base of the extractor (step three). In step four, the mixture of solvent and organics left the top of the extractor and was expanded across a valve prior to passing to a separator. The reduction in pressure caused the solvent to vaporize through the top of the separator. It was then collected and recycled through the compressor as fresh solvent (step five). The liquid organics left behind were drawn off from the separator and pumped to storage (step six).

About 1 to 2 hours were required to run a feedstock through the PCU. Test 2 involved passing, or recycling, the feedstock 10 times. Test 3 involved three passes and Test 4 involved six passes. Samples were taken from the feed kettle, extract collection tank, and treated sediment tank.

1.5 PROJECT ORGANIZATION

Through a Cooperative Agreement between EPA and CF Systems Corp., CF Systems was responsible for operating their equipment and EPA prepared the demonstration plan, prepared the test site, arranged for the sampling plan analyses, conducted sampling, evaluated the data, and prepared the Technology Evaluation Report. The evaluation included the following activities:

- Preparation of staging area to support testing, equipment setup, and health and safety orientation of field staff

- Pre- and post-demonstration sampling and analysis of staging area soils
- Public information meetings held to review CF Systems technology and tests on New Bedford Harbor sediments
- A shakedown test, three extraction tests, and equipment decontamination
- Staging area closure and disposal of waste materials.

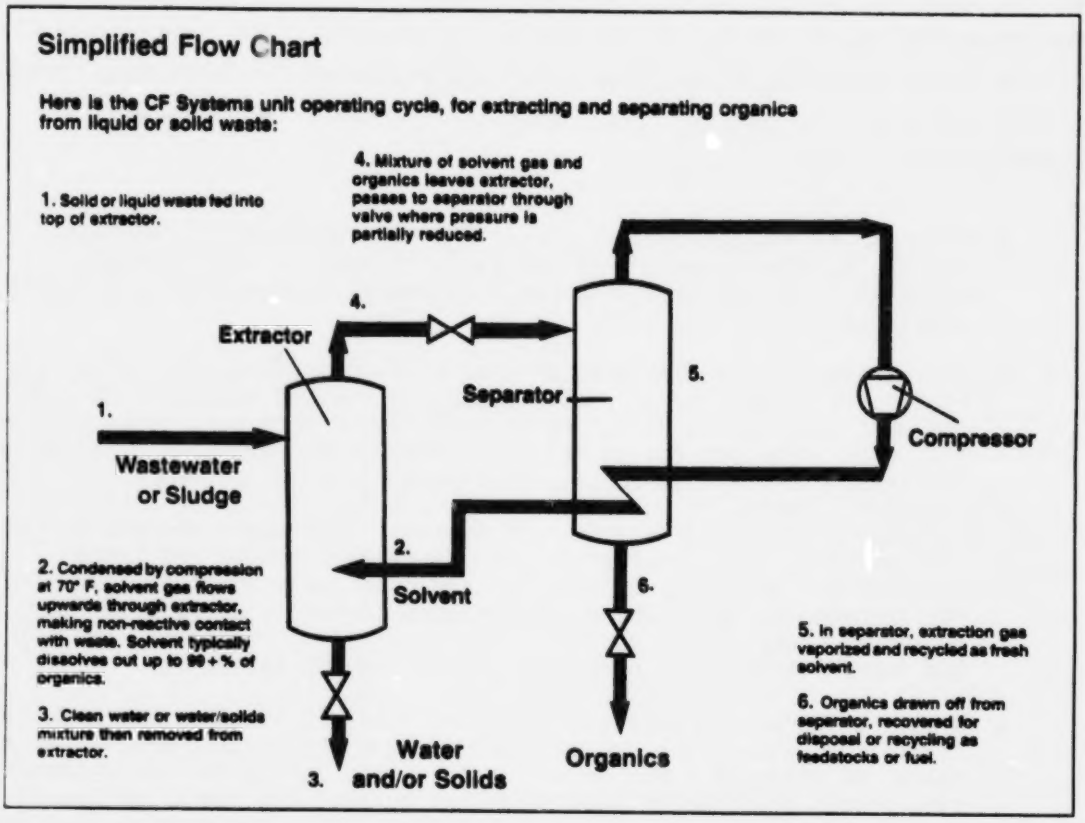

Simplified Flow Chart
Here is the CF Systems unit operating cycle, for extracting and separating organics from liquid or solid waste:
1. Solid or liquid waste fed into top of extractor.
4. Mixture of solvent gas and organics leaves extractor, passes to separator through valve where pressure is partially reduced.
Extractor
Separator
Compressor
Wastewater or Sludge
Solvent
Water and/or Solids
Organics
2. Condensed by compression at 70° F, solvent gas flows upwards through extractor, making non-reactive contact with waste. Solvent typically dissolves out up to 99+% of organics.
3. Clean water or water/solids mixture then removed from extractor.
5. In separator, extraction gas vaporized and recycled as fresh solvent.
6. Organics drawn off from separator, recovered for disposal or recycling as feedstocks or fuel.

Figure 1.1 Simplified Flow Chart

SECTION 2

SUMMARY OF RESULTS

The program obtained a large amount of analytical and operating data and was able to evaluate the four criteria stated in Section 1.3. A summary of the results, which correspond to the program objectives, is presented below.

2.1 SYSTEM PERFORMANCE

The performance of the treatment unit was evaluated in terms of extraction efficiency and a mass balance. Extraction efficiency per pass is defined as the input PCB concentration minus the output PCB concentration divided by the input PCB concentration (multiplied by 100 percent). An inventory of system inputs and outputs was established and evaluated for total mass, total solids, and the total mass of PCBs. Results of these evaluations are summarized as follows:

- PCB removal efficiencies of 90 percent were achieved for sediments containing PCBs ranging from 350 to 2,575 ppm. A high removal efficiency was achieved after several passes, or recycles, of treated sediments through the unit.

- Extraction efficiencies greater than 60 percent were achieved on the first pass of each test. Later passes of treated sediments through the unit resulted in efficiencies that ranged from zero to 84 percent. This wide range was due to solids retention in the system. Solids retained in the system cross-contaminated treated sediments that were recycled. Recycling was necessary to simulate the peformance of a full-scale commercial system. CF Systems' full-scale designs do not include recycling, since additional extraction stages and longer processing times are involved. In addition, only 50 to 150 gpd were run through the unit, which was designed to handle up to 2,160 gpd. Therefore, some solids may have been retained in equipment dead spaces and intermittently discharged during subsequent passes.

- A mass balance was not established for PCBs. A total of 157 grams was fed to the unit during system shakedown and Tests 2, 3, and 4. Of the total, 80 grams were accounted for in system effluents. Decontamination washes produced an additional 169 grams. The sum of effluents and decontamination washes was, therefore, 101 grams greater than that fed to the unit. This imbalance may be the result of limitations of the analytical method. PCB analytical Method 8080 precision criteria established for this project were plus or minus 20 percent and accuracy criteria were plus or minus 50 percent. In addition, the mass balance calculation was dominated by the Test 4 feed concentration. Therefore, error associated with the Test 4 feed sample

could also be a source of the PCB mass imbalance. Another possibility is contamination of the PCU from prior use at other sites. CF Systems did not decontaminate the unit with toluene prior to the tests at New Bedford. CF Systems' standard operating procedures now incorporate decontamination with toluene.

- A good mass balance was established for total mass and solids through the system. A total of 3-1/2 tons of solids and water were fed to the unit during Tests 2, 3, and 4. Of the total, 96 percent was accounted for in effluent streams. A total of 789 pounds of solids were processed during Tests 2, 3, and 4. Of the total, 93 percent was accounted for in effluent streams. The slight imbalances, 4 and 7 percent, are attributed to the inaccuracy of the weighing device (1 percent), sample error, and accumulation of mass in system hardware.

- Metals were not expected to be removed from the sediments, and were not removed during the extraction. EP Tox test results indicate that metals did not leach from either treated or untreated sediments. Characteristics of the sediments, with respect to the EP Tox test, were not changed by the treatment process, although high concentrations of metals were present. Copper and zinc typically exceeded 1,000 ppm. Chromium and lead concentrations ranged from 500 to 1,000 ppm.

- The decontamination procedure showed that PCBs were separated from the sediment during the tests since nearly all of the PCBs were contained in extract subsystem hardware. Of the 81 grams of PCB fed to the unit during Tests 2, 3, and 4, only 4 grams remained in the final treated sediments. Subsequent decontamination of the PCU with a toluene wash showed that some PCB had accumulated in system hardware. However, 91 percent of the PCBs contained in decontamination residues were found in extract subsystem hardware.

- A QA/QC review showed that analysis data of PCBs in sediments for Tests 1 through 5 were sufficiently accurate and precise for an engineering assessment of the efficiency of this demonstration.

2.2 OPERATING CONDITIONS

Operating conditions essential to the efficient performance of the PCU were manually controlled and monitored during Tests 2, 3, and 4. Operating conditions included feed temperature, particle size, flow rate, pH, and solids content; solvent flow rate and solvent/feed mass ratio; and extractor pressure and temperature. The unit generally performed as predicted by the developer, although some deviations from the planned specifications occurred. An evaluation of operating conditions is summarized as follows:

- Feed flow rates and extractor pressures were controlled throughout the tests within specified ranges. Feed flow rates ranged from 0.6 to 1.4 gpm. Extractor pressures ranged from 190 to 290 psig.

- During Test 2, feed temperatures for the last 4 passes were 10 degrees F lower than the minimum specification, 60 degrees F. Decreased extraction efficiency, which was apparent during this test, may have been related to low feed temperatures. Sustained low temperatures could have the effect of seriously reducing extraction efficiency in a full-scale commercial system.

- Solvent flow fluctuated as much as 75 percent above and below the nominal flow rate, 12 lb/min. In Test 2, Pass 1 this caused the solvent-to-feed ratio to fall below specifications. This could affect the extraction efficiency in full-scale system, since less solvent would be available to extract organic pollutants from the feed soil.

- Specifications for maximum particle size, one-eighth inch, were met by sieving sediments through a screen. This was necessary to prevent damage to system valves. Less than 1 percent of the sediment particles were greater than one-eighth inch.

- Specifications for maximum viscosity, 1,000 centipoise, were met by adding water to form a pumpable feed mixture. Feed viscosities ranged from 25 to 180 centipoise. The mass of waste increased by about 33 percent, because unit operators arbitrarily added water.

- Solids contents ranged from 6 to 23 percent and fell below the minimum specification, 10 percent, after the fourth pass of Tests 2 and 4. A 10-percent minimum spec was set merely to ensure that the technology would be demonstrated for high solids content feeds.

- EPA and the developer will address corrective measures for operational controls and material handling issues. However, these measures are not the subject of this report.

2.3 HEALTH AND SAFETY CONSIDERATIONS

The Health and Safety Plan established procedures and policies to protect workers and the public from potential hazards during the demonstration. Some observations, based on an evaluation of health and safety monitoring conducted during the demonstration, were:

- Combustible gas meters indicated that the unit did not leak significant amounts of propane. Therefore, operation of the unit does not present an explosion threat much different than that associated with domestic propane usage. Background air sampling and personnel monitoring results indicate that organic vapors and PCB levels were present at levels below the detection limit for the analytical methods.

- The unit did not cause a sudden release of propane and butane or liquids. Only minor leaks occurred and staging area soils were not affected.

- The unit was not completely decontaminated before it left the site. Toluene was fed to the unit as a decontamination wash. Toluene wash was collected at the extract product tank and the two treated sediment product tanks. The final toluene wash from the treated sediment tank contained less than 34 ppm of PCBs. The final wash from the extract tank contained 60 ppm of PCBs.

2.4 EQUIPMENT AND MATERIAL HANDLING PROBLEMS

Equipment and system material handling problems occurred during the tests, although some problems were anticipated. Problems included:

- Internal surfaces of extractor hardware and piping collected PCBs as evidenced by mass balances for PCBs and subsequent washes of the unit with a refined naphtha fuel and later with toluene. The washes recovered accumulated PCBs as well as oil and grease. These accumulations of organics are believed to be the result of the short duration of the tests and the small volume of organics contained in the feed sediment, relative to the volume of the extraction system hardware. PCBs are soluble in oil and grease, which is believed to coat the internal surfaces of system hardware. Continuous operation of the unit has resulted in continuous discharge of extracted organics during other demonstrations of the technology.

- The unit intermittently retained and discharged feed material solids. This is the result of the relatively small volumes that were batch fed to the unit. The unit was designed for continuous operation, not short-term tests. In addition, only 50 to 150 gpd were run through the PCU, which was designed to handle up to 2,160 gpd. Therefore, some solids may have been retained in equipment dead spaces and intermittently discharged during subsequent passes.

- Solids were observed in extract samples, which were expected to be free of solids. This indicates poor performance or failure of the cartridge filter. An alternative type of filter should be investigated by the developer.

- Extractor and treated sediment hardware contained organic sludge from prior use of the unit at a petroleum refinery. Presence of the petroleum residuals prevented complete interpretation of data collected for oil and grease and semivolatile organics.

- Low-pressure dissolved propane caused foaming in the treated sediment product tanks. This hindered sample collection and caused frequent overflow of treated sediment to a secondary treated sediment product tank. CF Systems states that design of a commercial-scale unit will allow release of propane entrained in the treated sediment and eliminate the foaming.

2.5 LESSONS LEARNED

Lessons learned that could be useful in planning future technology demonstrations are discussed in this section. The lessons learned center on demonstration preparation and logistics, treatment goals, and sampling and analysis for PCBs.

Demonstration Preparation and Logistics

- The developer's equipment must be decontaminated prior to being brought on site. Quality Assurance Project Plans (QAPPs) should include predemonstration sampling and analysis to ensure that the technology is free of contaminants. The PCU contained residue from a prior demonstration at a petroleum refinery. In addition, the system carbon canister, which receives vented low pressure gas, had not been changed.

- The developer must commit time needed to decontaminate the unit before and after the demonstration, to conduct preventive maintenance, and to respond to required sampling protocol. No equipment failures occurred at New Bedford; however, a week was added to the schedule while preventive maintenance was conducted.

- The generation of trash (e.g., gloves and Tyvek suits) and process residue can be substantial. Adequate provisions should be made for waste residue and trash management. Program personnel and the developer should develop realistic projections of the amount of process residues and trash that will be produced as a result of the demonstration. At New Bedford, 87 drums of waste were produced, compared with 3 drums of harbor sediments fed to the unit. The large volume of waste resulted from water added to the feed; water used to decontaminate personnel and sampling gear; and trash, such as gloves and Tyvek suits, that were not compacted.

Developer's Input

- The developer should provide specific protocol for conducting shake-down tests. This protocol should distinguish process control from onsite process optimization.

- The developer should provide a basis or a design procedure for scaling up bench- or pilot-scale test results to a commercial-scale system and for correlating batch test results to operation of a continuously fed unit.

Sampling and Analysis Methods

- Interpretation of results from any PCB treatability study should include a discussion of the precision of the analysis method.

- A portable gas chromatograph GC and a chemist should be available onsite to allow a rapid response to changes in feed composition or operational control. The Spittler Method was used at New Bedford as a more timely alternative to EPA methods. However, even with this method, 24 hours were required for sample shipment and subsequent analysis.

- The unit did not selectively extract one class of PCBs. Reviewers suggested the use of EPA Method 680, since the CF Systems technology could have selectively extracted higher molecular weight PCB congeners. Method 680 would reveal any selective extraction, since this method is used to analyze individual PCB congeners. Method 8080, a less expensive analysis method, would not reveal selective extraction, since it is used to analyze mixtures of PCBs called Aroclors, instead of individual congeners. EPA Method 8080 was chosen over Method 680, since selective extraction was minor and it analyzes for the classes of congeners that constitute the majority of PCB contaminants (Aroclors 1242 and 1254) in the harbor sediments.

- Methods 680 and 8080 produced similar relative results, but very different absolute results. Use of Method 680 in Test 4 showed a PCB extraction efficiency of 96 percent and Method 8080 showed a similar efficiency, 87 percent. However, Method 680 showed an untreated sediment PCB concentration of 8,700 ppm, while Method 8080 showed 2,575 ppm. Data quality objectives were met for each measurement. Therefore, regulatory or engineering interpretation of future PCB analyses should include consideration of the analysis methods used.

Conclusions and Recommendations

- Even though solids retention caused cross-contamination of treated sediments, significant PCB removals occurred.

- System decontamination procedures showed that PCBs were separated from the sediment since nearly all of the PCBs were contained in extract subsystem hardware. Of the 81 grams of PCB fed to the unit during Tests 2, 3, and 4, only 4 grams remained in the final treated sediments.

- Bench-scale tests are useful for determining whether organics contained in a soil will be extracted by a liquefied solvent such as a propane-butane mixture. Bench-scale tests may also be used to determine if a liquefied solvent selectively extracts specific classes of organics, such as high or low molecular weight PCBs. Bench-scale tests, however, do not yield information relating to operational and material handling issues, such as pumpability, foaming, and temperature.

- Commercial-scale designs for application of the technology should ensure that operating specifications are maintained. Wide fluctuations in the feed-to-solvent ratio should be minimized, since extraction efficiency is directly related to the amount of solvent available for solubilizing organics contained in the feed. However, the technology does accommodate wide ranges in operating conditions. Solid wastes with viscosities up to 1,000 centipoise and solids contents of 60 percent can be fed to the unit.

- Feed materials are likely to be well below 60 degrees F throughout winter months, which could affect system performance. Therefore, heat must be added to sediments fed to a commercial-scale unit.

- Pretreatment technology will be required to condition feed materials. Coarse solids removal will be required to maintain feed sediment particle sizes below one-eighth inch and water must be added to ensure pumpability.

- Health and safety monitoring showed that OSHA Level B protection will be necessary for personnel handling system input and output. However, only OSHA Level C protection will be adequate for unit operators.

- Operations, materials handling and health and safety issues are addressed in the Application Analysis Report. Costs are estimated for several case studies involving the New Bedford Harbor Superfund site. A significant cost element for a full-scale system is extraction process equipment, which must be scaled to handle much higher throughputs (60 gpm) than the PCU (0.9 gpm). Full-scale extractors have 4 to 6 foot diameters as compared with the 18 inch diameter of the PCU extractors. Recommended pretreatment technology includes conveyors, screening, heat and water addition, and mixing and holding tanks. Post treatment technology includes treated sediment dewatering, wastewater treatment and reuse, holding tanks, conveyors, and disposal of treated sediments and extracted organics. Onsite analytical capabilities and health and safety program implementation are additional cost elements.

SECTION 3

PROCESS DESIGN

3.1 PROCESS DESCRIPTION

CF Systems Pit Cleanup Unit (PCU), shown in Figure 3-1, is a continuous processing unit that used a liquefied propane/butane mix as the extraction solvent. The solvent mix was 70 percent propane and 30 percent butane. For each of the 3 demonstration tests, a batch of approximately 50 gallons of sediments was fed to the unit at a nominal rate of 0.9 gpm. Feed viscosity was maintained below 1,000 cP, by adding water to produce a pumpable slurry. Particles greater than one-eighth inch were screened from the feed to prevent damage to valves. Sediments were pumped to the extractors, which were typically operated at 240 psig and 70 degrees F. Liquefied solvent was also pumped to the extractors at a rate of 2.3 gpm (10 lb/min) and mixed with the sediments. Organics, such as PCBs that are soluble in the liquefied solvent, were extracted. After extraction, treated sediments were decanted and separated from the liquefied solvent and organics mixture. The mixture flowed from the extractor and passed to a separator through a valve that partially reduced the pressure. The pressure reduction caused the solvent to vaporize and separate from the extracted organics. The solvent was recycled and compressed to a liquid for reuse in the system.

The PCU was not designed for large-scale remedial actions. Therefore, treated sediments were recycled, or passed through the unit to simulate operation of a commercial-scale unit. CF Systems' commercial-scale designs do not include recycling. These designs feature 60 gpm flowrates, several extraction stages, and longer processing times.

3.2 EQUIPMENT SPECIFICATIONS

The major pieces of equipment and their function are described in Table 3-1. Process equipment that contacted the solvent or feed materials were constructed of 316 stainless steel. All process pumps were constructed of stainless steel, and both compressors were made of carbon steel. All of the process equipment was designed to withstand temperatures and pressures that

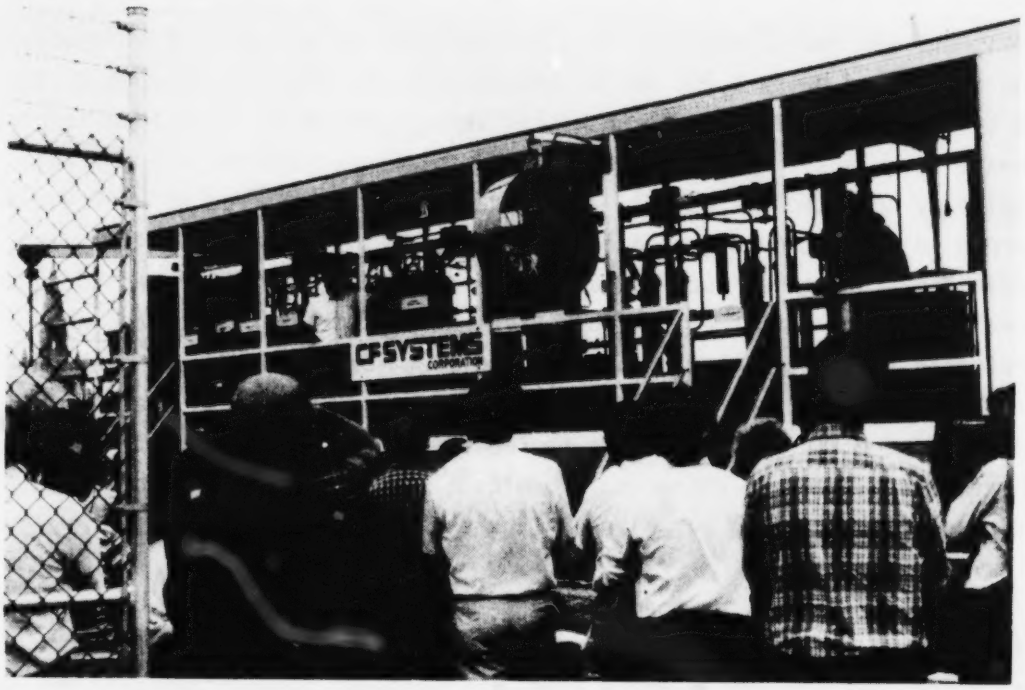


Figure 3-1. Pit Cleanup Unit

TABLE 3-1. PROCESS EQUIPMENT DESCRIPTION

Process Equipment	Designation	Function in System
Feed Kettle	FK	Holds approximately 100 gallons of strained, slurried feed. Counter-rotating agitators homogenize feed.
Basket Strainer	S-1	Prevents oversized (>1/8 inch) feed material from entering the system.
Extractor 1	E-1	Extracts organics from water-solids feed mixture with solvent from D-2.
Decanter 1	D-1	Allows separation of solvent-organic mixture from water-solids layer. Sends water-solids layer to Extractor 2 (E-2) and solvent-organics layer to the solvent recovery system.
Extractor 2	E-2	Extracts organics from water-solids mixture with fresh propane from the solvent recovery process.
Decanter 2	D-2	Allows separation of solvent-organics layer from water-solids mixture.
Cartridge Filter	F-2	Filters residual solid fines from solvent-organics stream leaving Decanter 1 (D-1).
Solvent Recovery Column	SRC	Separates propane solvent from organics via pressure reduction and heat from the Column Reboiler (CR). Solvent vapor flows out the overhead while organics are deposited in the CR.
Column Reboiler	CR	Provides both holdup for the recovered organics and heat for the Solvent Recovery Column (SRC) via a tube bundle heat exchanger.
Treated Sediment (Raffinate) Product Tank	RPT-1 RPT-2	Receives treated sediments (raffinate) from Decanter 2 (D-2). Recovers residual propane via flash pressure reduction and heat from water jacket. RPT-2 receives RPT-1 overflow.
Extract Product Tank	EPT	Receives extracted organics effluent from the Column Reboiler (CR). Recovers residual propane via flash pressure reduction and heat from the water jacket.

TABLE 3-1. PROCESS EQUIPMENT DESCRIPTION (Continued)

Process Equipment	Designation	Function in System
Main Compressor	C-1	Compresses both Low Pressure Solvent Compressor (C-2) outlet solvent and Solvent Recovery Column (SRC) overhead solvent. Outlet sent to Column Reboiler (CR) for heat exchange before returning to Extractor 2 (E-2).
Low Pressure Solvent Compressor	C-2	Compresses scavenged propane from Extract and Raffinate Product Tanks (EPT, RPT-1, and RPT-2). Sends compressed solvent to Main Compressor (C-1).

TABLE 3-2. RANGE OF OPERATING CONDITIONS FOR TESTING

	Minimum	Nominal	Maximum
Extractor Pressure (PSIG)	180	240	300
Extractor Temp. (degrees F)	60	100-110	120
Feed Temp. (degrees F)	60	70	100
Solvent Flow (lb/min)	8	12	15
Feed Flowrate (GPM)	0.2	0.2-0.5	1.5
Solvent/Feed Ratio	1	1.5	2
Feed Solids (percent by weight)	10	30	60
Solids Size (maximum)	--	--	1/8 inch
pH (standard units)	6	7	12
Viscosity (cP)	0.5	10	1,000

exceed normal operating conditions. To guard against sudden overpressure, each vessel had a relief valve that vented to a header system that discharged to the pollution control system.

The utility and process materials requirements that were necessary to operate the PCU at New Bedford Harbor were:

- Electricity--480 VAC 3 Phase, 100 amps
- Process Water--5 GPM, 60-80 degrees F inlet, 30-90 psi
- Potable Water--Available
- Propane--four, 100 gallon bullets, 95-97 percent purity
- Butane--As needed, for Propane/Butane (70/30) solvent mix
- Nitrogen (for pressure testing during shakedown period)--(2) 1A size cylinders.

Utility usage for a commercial-scale unit cannot be easily compared with the PCU because pilot-scale equipment consumed much more energy per gallon of throughput.

The operating conditions listed in Table 3-2 are essential to the efficient operation of CF Systems' pilot-scale unit. Failure to operate the unit within the specified operating ranges can result in decreased extraction performance. The operating parameters were set during the shakedown portion of the demonstration. CF Systems claimed that minor fluctuations would not affect performance.

The feed temperature is that of the material piped into the feed kettle. The feed must be maintained above 60 degrees F to avoid freezing, which could interfere with the extraction process. The feed must be maintained below 120 degrees F to prevent vaporization of the solvent.

The extractor pressure, measured at the gauges on extractors 1 and 2, is controlled by the main compressor and at the extract discharge from the extraction segment of the unit.

The viscosity and solids content must be such that the feed material is pumpable. Pretest sampling determines the viscosity of the potential feed. Any potential feed with a viscosity above the listed range is slurried with water to yield a pumpable mixture.

In order to prevent damage to the process equipment, the pilot-scale unit has a maximum limit for solids size. Basket strainers, located between the feed pump and the first extractor, prevent larger-than-allowable size solids from entering the system. Oversized solids removed from the feed were hauled to a RCRA-approved facility.

The feed flow rate represents the rate at which material is pumped from the feed kettle into the extraction system. Operational flow rates above the listed maximum can force segments of the system, such as decanters and control valves, beyond their effective hydraulic capacity. The feed flow rate is manually controlled through the feed pump controller located beneath the feed kettle. Average detention time of throughput is about one hour.

3.3 PROCESS FLOW DIAGRAM

The PCU process flow diagram is shown in Figure 3-2. The extraction portion of this unit consisted of two stages of counter-current extraction with solid-liquid separation between the extractors. The feed was transferred from a feed preparation drum to the feed kettle with a pump. In the feed kettle, slurry solids were kept suspended while in the feed kettle by two counter-rotating agitators. During this process, feed was pumped from the feed kettle through a basket strainer, which removed any particles greater than 1/8 inch in diameter. Then feed flowed to the first extractor, where feed was mixed with the liquid propane/butane solvent. An agitator (not shown in the figure) provided mixing action before the solvent-organics mixture flowed to decanter 1. At decanter 1, the mixture separated into two immiscible layers. The solids and water settled into the underflow to the second extractor. The decanter overflow, which contained extracted organics, propane/butane, and fine solids, flowed through a filter and then to a solvent recovery column.

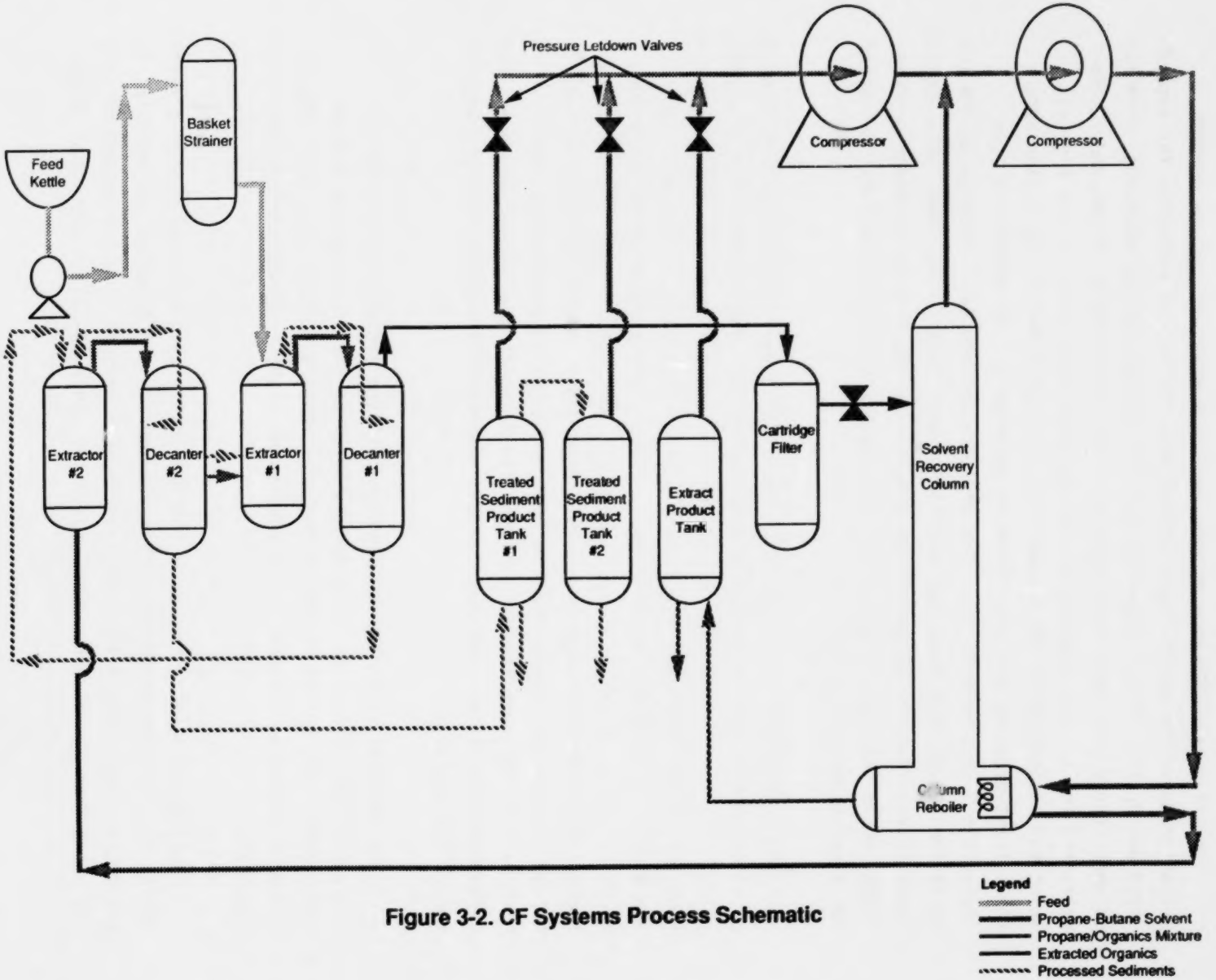


Figure 3-2. CF Systems Process Schematic

The pressure difference between the first decanter and the second extractor moved the solid-liquid stream into the second extractor for second-stage extraction. Fresh liquefied solvent (propane/butane mixture) from the solvent recovery process then mixed with the solids/water stream and further extracted the organic components. An agitator (not shown in the figure), which was located above the second extractor, provided mixing action before the solvent-organics mixture flowed to decanter 2. At decanter 2, two immiscible layers were formed. The organics-solvent layer floated to the top while the solids sank into the underlying water layer. The lower water-solids layer flowed from the bottom of the decanter to the treated sediment product tanks, while the upper organics-solvent layer recycled to the first extractor for final stage extraction.

The organic-solvent stream from the first stage extractor passed through a filter cartridge that collected fine solids and went to the solvent recovery column. In the solvent recovery column, the solvent vaporized and was removed from the column overhead, while the organics remained as a separate liquid. The mixture of organics containing dissolved propane gathered in the column reboiler and subsequently passed to the extract product tank. Solvent from the column overhead flowed to the main compressor. The compressed solvent passed through the column reboiler heat exchanger to provide the heat necessary to boil off residual solvent remaining in the organic mixture. The condensed solvent left the reboiler and re-entered the extraction system via the second extractor.

The residual solvent that vaporized off the system products in the extract or the treated sediment tanks flowed to the low-pressure solvent compressor. The outlet stream of the low-pressure solvent compressor fed to the main compressor, where it was compressed along with vapors from the column overhead.

During system shutdown or if overpressure within a vessel opened a relief valve, material was vented to a relief header, which directed the material to a blowdown tank where solids and liquids were removed from the vented stream. The gases from the blowdown tank passed through a 42-gallon activated carbon

filter to remove contaminants in the propane gas. The gas then passed through a flame arrestor and was vented to the atmosphere. This system was used only once during the demonstration, at the conclusion of PCU decontamination.

SECTION 4. DEMONSTRATION SITE DESCRIPTION

4.1 SITE CHARACTERISTICS

The site selected for demonstration of CF Systems' process was New Bedford Harbor, located in New Bedford, Massachusetts. During the 1970s, PCBs and other contaminants were identified in the sediments and marine life of New Bedford Harbor and parts of Buzzard's Bay. Studies conducted by EPA in 1980 led to New Bedford Harbor being proposed in 1982 for EPA's National Priorities List. The main areas of New Bedford Harbor under EPA investigation are the Acushnet River Estuary and the harbor. The estuary is the area of the site north of the Coggeshall Street Bridge shown in Figure 4-1. Areas of extremely high PCB contamination are located at the northern tip of the estuary. The lower harbor includes Buzzard's Bay and the waters below the Coggeshall Street Bridge. The demonstration took place on a parcel of city-owned property adjacent to the cove north of the Coggeshall Street Bridge, as shown in Figure 4-1. Area within the dashed line was also the site for a pilot dredging and disposal study conducted jointly by EPA, the Massachusetts Department of Environmental Quality Engineering, and the U.S. Army Corps of Engineers (COE).

PCB concentrations in the harbor range from a few ppm to more than 30,000 ppm and elevated levels of copper, chromium, zinc, and lead also are present at the site (COE, 1987). Most organic compounds detected in sediments are co-located with PCBs and occur at concentrations less than or equal to the observed PCB concentrations (Ebasco, 1987). An evaluation of the relative toxicities of PCBs indicates that the environmental and public health risks from sediment exposure will be dominated by the PCB constituents. However, some polynuclear aromatic hydrocarbon (PAH) compounds occur at certain locations, and at concentrations that may significantly contribute to the overall environmental and public health risk associated with exposure to the sediments.

PCBs consist of a mixture of chlorinated biphenyls, which contain a varying number of substituted chlorine atoms on aromatic rings. The persistence of PCBs in the environment and their toxicity increases as the chlorine content increases. The commercial products of the complex chlorobiphenyls

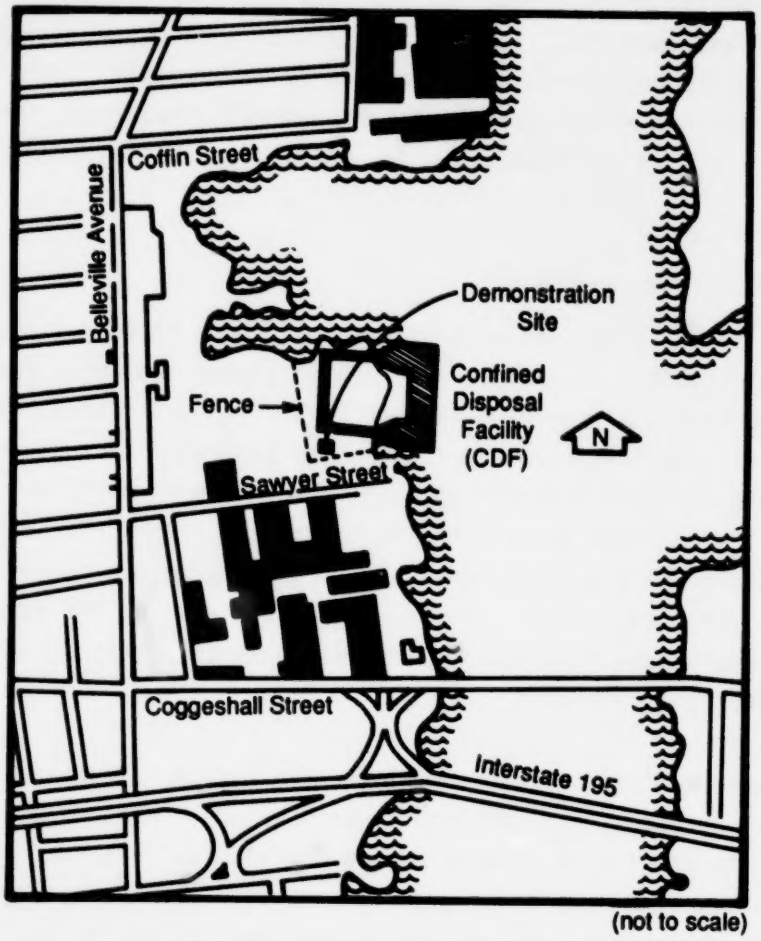


Figure 4-1. Demonstration Location

were registered and manufactured under the trademark "Aroclor." Fifty percent of the congeners in the New Bedford Harbor area of interest have been identified as Aroclors 1242 and 1254. Therefore, PCBs were measured using the Aroclor 1242 and 1254 standards.

Based on the available literature (COE 1987, Ebasco 1987), the pollutants of concern were determined to be PCBs, semivolatile organics (which includes PAHs), cadmium, chromium, copper, zinc, and lead. CF Systems requested analyses for additional parameters to evaluate the overall system performance. Oil and grease was used by CF Systems as a process control parameter since the majority of organic pollutants are extracted by the process. Total solids, pH, and viscosity can affect equipment performance. Therefore, these parameters were chosen for monitoring in addition to the pollutants of concern.

4.2 PREDEMONSTRATION SAMPLES

COE dredged collected sediment from the Acushnet Estuary for use in this demonstration project. An attempt was made to gather sediments from areas with differing levels of contamination so that a range of concentrations would be available for the demonstration. Collected sediments were stored in drums that were assigned identification numbers. Drum Numbers H-20, H-21, H-22, H-23, and I-11 were later used in the demonstration. The drum identification numbers correspond to a grid system used by COE in previous harbor characterization work. This grid system shown in Figure 4-2 enabled COE to estimate probable concentrations from particular areas to ensure that an appropriate range of samples was collected.

The drummed sediments were conditioned for predemonstration sampling by removing solids greater than 1/8 inch, adding water to produce a slurry, and stirring. Contents of each drum were hand-shoveled and sieved through a 1/8-inch screen into a second drum. More than 99 percent of the solids were passed through the screen. As the second drum was filled, harbor water was added to produce a stirrable slurry. Slurried contents were manually stirred with a shovel and three samples were drawn after 15 minutes of mixing. Samples from each drum were analyzed for PCBs, oil and grease, pH, total

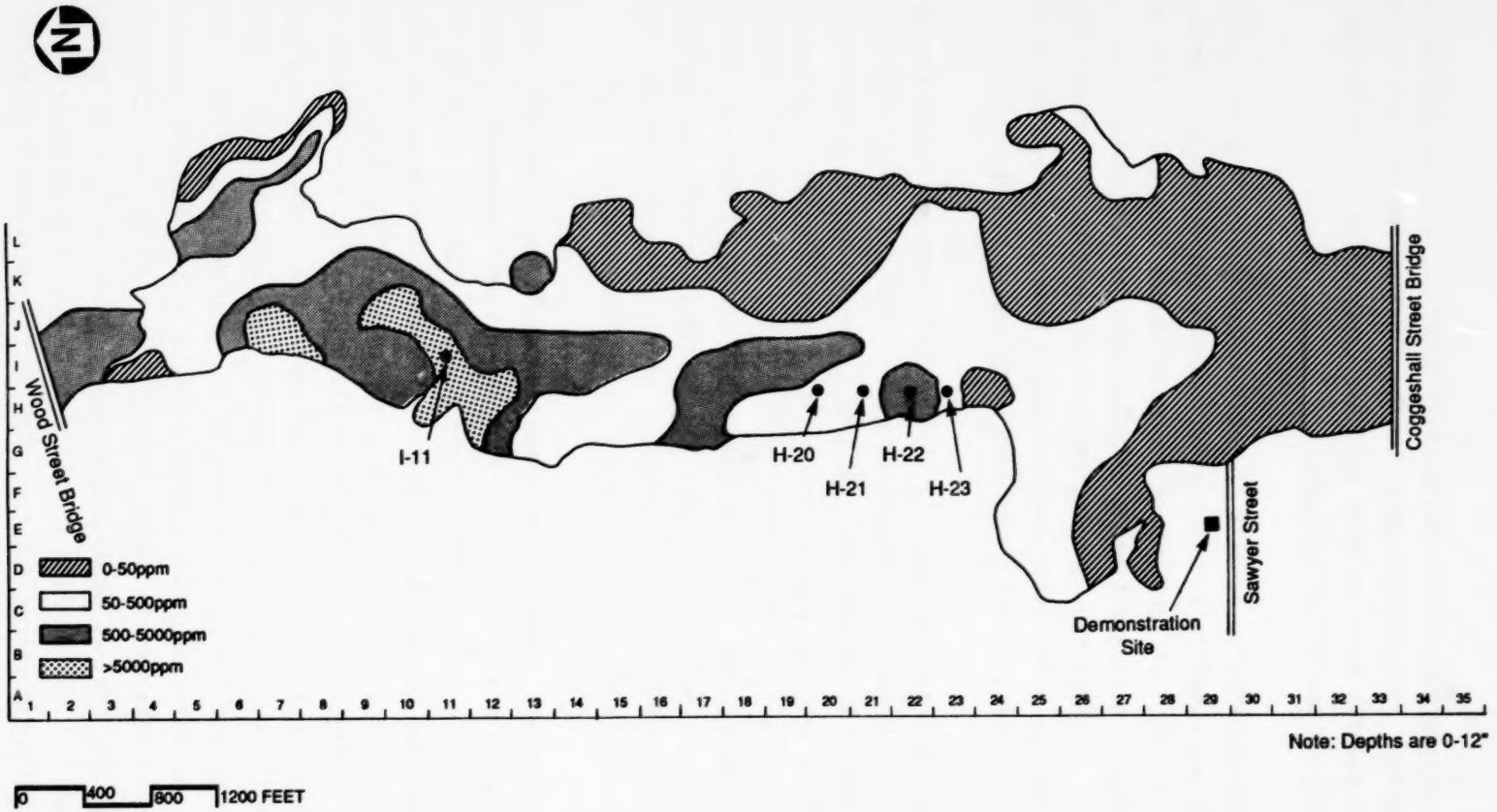


Figure 4-2. Predemonstration Samples

solids, moisture content, semivolatile organics, and sediment particle size distribution. The methods used for the sampling and analysis of predemonstration samples were the same as those used during the tests (see Section 6.3 for a list of analytical methods).

Predemonstration results of total solids, oil and grease, PCB, and pH analyses are summarized in Table 4-1. Total solids ranged from 29 to 45 percent solids. Oil and grease contents ranged from 1.5 to 7.8 percent. No correlation was apparent among total solids, oil and grease, and PCB concentrations. As expected, the sediments from location I-11 contained PCBs well over 5,000 ppm. The other samples ranged from 160 to 640 ppm of PCB. The range of pH was 7.3 to 8.2 standard units among the samples.

Data reported for particle size distribution and semivolatile organics were similar among the drummed sediments. Particle size distributions were approximately 37 percent sand, 41 percent silt, and 22 percent clay for each drum. PAHs were the predominant class of semivolatiles, as expected, based on the literature (COE 1987, Ebasco 1987). PAHs detected in each of the 5 drums included napthalene, acenapthalene, dibenzofuran, fluorene, phenanthrene, anthracene, di-n-butylphthalate, fluoranthene, pyrene, benzo(a)anthracene, chrysene, bis(2-ethylhexyl)phthalate, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene and benzo(g,h,i)perylene.

A composite sample and a composite sample replicate were obtained for overall waste characterization, from the drummed sediments selected for the demonstration. Also included in these composites were aliquots from four drums not used in the demonstration. The composites were analyzed for 23 metals, cyanide, volatile organics, and extraction procedure (EP) toxicity metals. Analysis results for 23 metals and cyanide are shown in Table 4-2. Metals and cyanide analysis results compare well with previous studies that showed high levels of copper, chromium, lead, and zinc (COE, 1987). EP tox metals data are discussed in Section 7.1, and were less than RCRA regulatory limits. Volatile organics analyses were run for 34 parameters and the following were detected at levels greater than 1 mg/Kg; vinylchloride, methylene chloride, acetone, toluene, 1,2-dichloroethene, 2-Butanone, and ethylbenzene. The volatile organics data are not critical to this demonstration since the measured concentrations are low relative to semivolatile organics data.

TABLE 4-1. PREDEMONSTRATION RESULTS OF TOTAL SOLIDS, OIL AND GREASE, PCB, AND pH ANALYSES

Sample (a)	Concentration Total Solids (percent) (b)	Concentration Oil and Grease (percent) (b)	Concentration PCB ppm (b, c)	pH (Range in Standard Units)
H-20	29	3.3	402	7.3-8.2
H-21	34	1.5	333	7.6-8.1
H-22	30	7.8	640	7.7-7.8
H-23	43	1.2	162	7.8-8.2
I-11	35	7.1	32,333	7.3-7.6

(a) Sample designations refer to the drummed sediments obtained by COE from the locations shown in Figure 4-3.

(b) Represents the average of 3 grab samples taken from each drum.

(c) Polychlorinated biphenyl (PCB) reported as the sum of Aroclors 1242 and 1254.

TABLE 4-2. PREDEMONSTRATION RESULTS OF METALS ANALYSES

Parameter	Concentration (mg/kg) (1)
Aluminum	10,000
Antimony	8
Arsenic	12
Barium	140
Berylium	4
Cadmium	29
Calcium	2,550
Chromium	425
Cobalt	9
Copper	900
Iron	16,500
Lead	590
Magnesium	5,300
Manganese	185
Mercury	1.4
Nickel	130
Potassium	2,200
Selenium	ND (2)
Silver	4
Sodium	11,000
Thallium	ND
Vanadium	70
Zinc	1,850
Cyanide	Less than 6

Notes: 1. Data reported are the mean of 2 grabs from a composite of predemonstration samples.

2. ND indicates not detected.

SECTION 5. FIELD ACTIVITIES

SITE Program activities were conducted for the CF Systems New Bedford Harbor demonstration program from June to October, 1988. In July, the U.S. Army Corps of Engineers (COE) obtained drummed samples of harbor sediments. CF Systems conducted bench-scale tests on archived sediment samples in June and later, in August, conducted bench-scale tests using the COE samples. Public meetings were held and a Fact Sheet was distributed throughout June, July, and August. The demonstration was conducted in September.

The bench-scale tests are described in Section 5.1. The plans for the demonstration are described in Section 5.2. A summary of the actual operations is described in Section 5.3. The few operational deviations from the Demonstration Plan are also discussed in Section 5.3 along with some additions to the analytical testing program that were incorporated into the Program while at the site.

5.1 BENCH-SCALE TESTS

Bench-scale tests were conducted, prior to the demonstration, in order to determine the best operating conditions for the PCU. Bench Test 1 consisted of extracting PCBs from three different sediment samples. In Bench Tests 2 and 3, a fourth and fifth sample were run. Each sample was divided into 3 portions and each portion was extracted at different solvent-to-feed ratios.

The bench-scale extraction apparatus consisted of a stainless steel, single-stage, counter-current extractor with a mechanical stirrer and a solvent delivery system. A nominal amount of material (between 180-190g) was placed in the extractor (about 0.8 liters capacity) at the beginning of a run. A portion of the remaining volume in the extractor was filled with solvent. The system was then pressurized to 150-200 psig at an ambient temperature of 70-80 degrees F. The stirrer activated and the contents were mixed. After a suitable residence time, the stirrer was switched off and the contents allowed to settle. The system was depressurized in order to permit collection of raffinate and extract samples.

Test data are shown in Table 5-1 that include the test number, sample number, feed PCB concentration, and treated sediment PCB concentration for respective solvent-to-feed ratios. The data generally show that higher ratios of solvent-to-feed used in the extraction result in higher extraction efficiencies. However, data for sample 2 (ratio 20:1) and sample 4 (ratio 2:1) do not show this trend. These differences may be attributed to the range of accuracy associated with the screening method used to analyze PCBs in each sample.

CF Systems used the data in Table 5-1 to roughly estimate the number of passes required to treat wastes to specific levels in the demonstration. For example, the single-stage bench test results for sample 4 showed that 210 ppm could be reduced to 17 ppm with a 20-to-1 feed-to-solvent ratio. Therefore, CF Systems estimated that the two-stage PCU would require 10 passes, or recycles, at a 1.5-to-1 feed-to-solvent ratio to achieve a similar reduction.

Bench-scale tests were useful for confirming the solubility of PCBs in the liquefied solvent. However, these tests were only of limited use for setting PCU operating conditions. In addition, the bench-scale tests did not provide data relating to operational and material handling issues such as temperature requirements, foaming, and pumpability.

TABLE 5-1. BENCH-SCALE TEST DATA

Test Number Sample Number		1 1	1 2	1 3	2 4	3 5
Sample	Solvent/Feed Ratio	PCB Concentration (ppm)				
Feed	(Not Applicable)	6,200	210	5,300	210	11,000
Treated Sediment	2:1	4,600	170	4,000	340	5,800
Treated Sediment	10:1	3,800	23	1,600	57	940
Treated Sediment	20:1	3,300	68	430	17	220

5.2 OPERATIONS SUMMARY

CF Systems' pilot unit occupied a 60- by 100-foot staging area adjacent to Sawyer Street, as shown in Figure 5-1. The staging area, covered with an aggregate base of crushed 3/4-inch stone with a 6-inch depth, was amenable to both tractor trailer and hand-cart traffic. An 8-foot high, chain-link fence topped with 2 feet of barbed wire cordoned off the staging area from the remainder of the EPA-COE controlled location. An 18-foot wide gate provided access to the site. Access to the demonstration test staging area was provided through a hard-packed earth roadway running through the EPA-COE area. This roadway exited onto Sawyer Street. Security for the demonstration test staging area was provided 24 hours per day.

The overall procedure started with preparing sediments for feeding to the PCU for each test. Sediments previously collected by COE and stored in drums were sieved to remove particles greater than 1/8 inch and other debris, such as leaves and sticks. The sieving apparatus consisted of a custom-made steel rim, a removable 1/2-inch screen, and a removable 1/8-inch screen. Initially, both screens were being used, but after several days of sieving, it was determined that only the 1/2-inch screen was necessary because the 1/8-inch screen was not catching any additional material not already caught by the 1/2-inch screen. Later, during test 1, CF Systems expressed concerns that oversized feed material was interfering with the unit's pumps. In order to determine whether oversized materials had not been sieved out of the feed material, the feed material from the test was sieved through an aluminum window screen (1/8 inch) placed on top of the 1/8-inch sieve originally used on the drum samples. A small amount of humus material was caught between the two screens. Sediments were shoveled onto the screens, which were placed over an empty drum. A trowel was used to push the sediments through the screens and harbor water was used to wash the sediments into the drums. Feed prepared for each test was pumped into the feed kettle.

Each of the four tests were run similarly except that number of passes and PCB concentrations were varied for each test. A pass was defined as one cycle of the feed through the PCU. A pass of feed results in a treated sediment product and an extract product. Collecting and recycling the treated

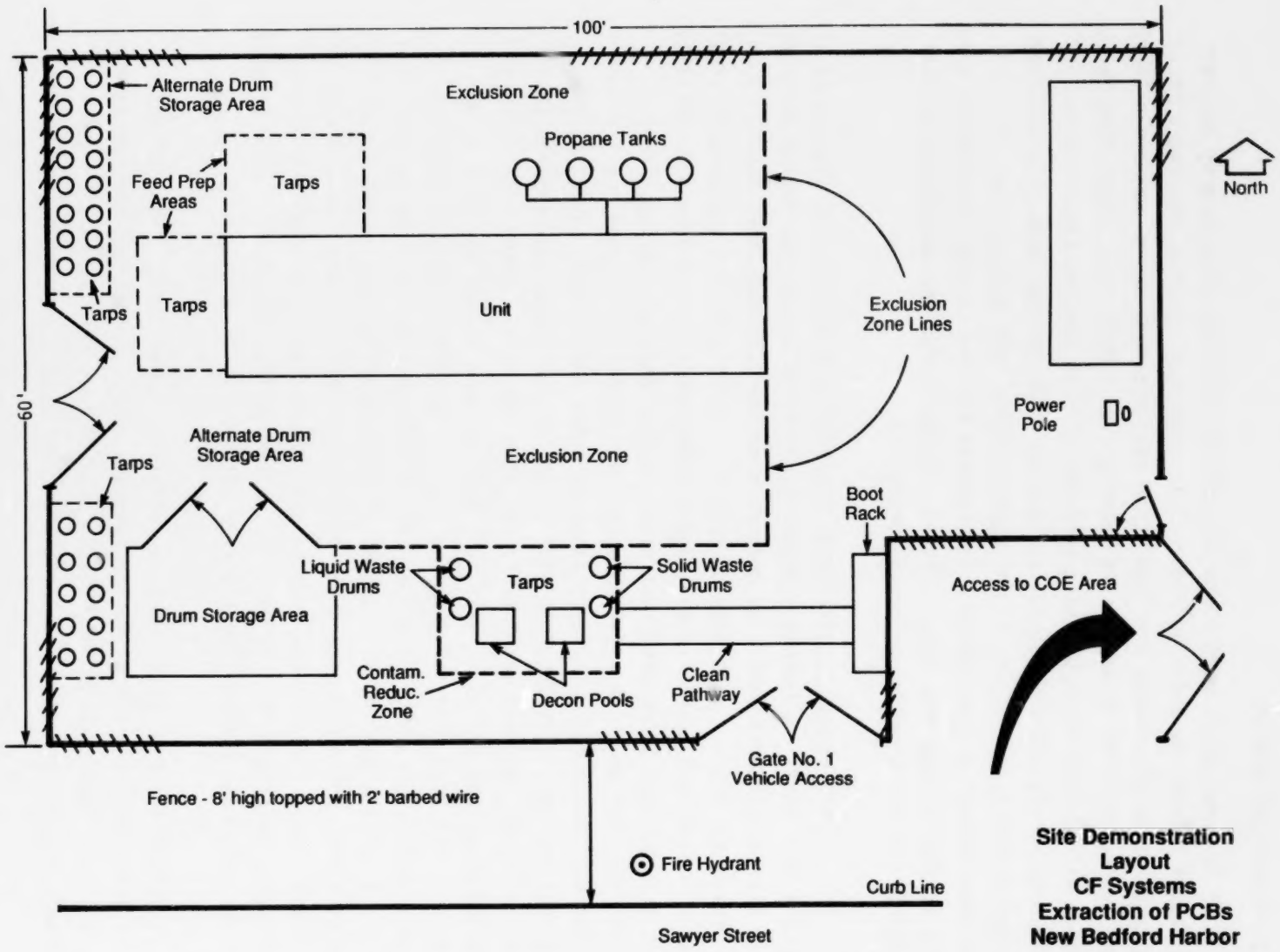


Figure 5-1. Plan Sketch for New Bedford Harbor Demonstration

sediment through the PCU constituted an additional pass. Recycling was conducted to simulate the operation of a full-scale commercial system. The PCU is only a two-stage system, whereas commercial designs include four or more stages, longer extractor residence times, and longer phase separation times. Conditions that varied for each test were:

1. Test 1 was run as a shakedown test to set pressure and flowrates in the PCU. The feed was a 50-gallon composite of sediments taken from drum numbers H-20, H-21, and H-23. The feed had a PCB concentration of 360 ppm. Three passes were run to gain experience with materials handling.

2. Test 2 was a 10 pass test. The feed was a 350 ppm, 511 pound composite of sediments taken from drum numbers H-20, H-21, and H-23. Ten passes were run to simulate a high-efficiency process and to achieve treated sediment levels less than 10 ppm. A 350 ppm concentration was chosen for this test since this represents an average, or typical, PCB concentration in the harbor.

3. Test 3 was a 3 pass test. The feed was a 288 ppm, 508-pound composite of sediments taken from drum numbers H-20, H-21, and H-23. The purpose of this test was to reproduce the results of the first three passes of Test 2.

4. Test 4 was a 6 pass test. The feed was a 2,575 ppm, 299-pound composite of sediments taken from drum numbers I-11 and H-22. The purpose of this test was to reduce a high-level waste to a lower level waste such as that used in Tests 1, 2, and 3. High-level wastes are found at several "hot spots" in the harbor.

Decontamination of the system involved running toluene through the PCU as a solvent wash.

Samples were taken of the feed at the commencement of each test. Treated sediment products and extracts were planned for sampling at each pass. Additional samples were taken of system filters and strainers, although the amount of PCB contained in these miscellaneous samples later proved to be small. PCU operating pressures, temperatures, and flow-rates were monitored throughout the tests. Field tests were conducted for feed viscosity, pH, and temperature.

Information was logged in a notebook to report the sampling operations and the overall operations at the site. This included the following:

- Operating conditions, gage reading, mass and volume determinations
- Notes on daily preparations of CF Systems and EPA
- Problems
- Health and Safety related procedures, meetings, and concerns
- Chronology and summary of daily activities, including check-in and check-out of all personnel
- Weather conditions.

5.3 OPERATIONS CHRONOLOGY

The demonstration commenced at the New Bedford site on September 6 and continued until September 29. Test 1, the system shake-down, was conducted on September 6. Test 2 was conducted from September 8 through 18. Test 3 was conducted from September 18 through 20. Test 4 was conducted from September 20 through 29. System decontamination took place from September 30 through October 4. Highlights of the site preparation, operation, and decontamination are described below.

Test 1

The planned system shakedown, Test 1, consisted of three passes. Samples were taken at the following locations for PCB analyses:

- Feed kettle
- Treated sediment product tank
- Extract product tank.

The feed was a composite of sediments taken from COE drums nos. H-20, H-21, and H-23. The feed had a PCB concentration of 360 ppm. Field personnel reported that Pass 1 treated sediments contained some foam and appeared to have a very low solids content relative to the feed. A layer of foam several inches thick formed in the treated sediment collection drum during Passes 2 and 3. Since the foam hindered sampling, the treated sediment was allowed to degas in collection drums overnight. A Pass 1 extract sample was collected several days after the Pass 1 raffinate sample. This delay ocurred over a holiday weekend.

Test 2

Test 2 was a 10-pass test conducted on a low PCB concentration (350 ppm) sediment. The source of sediments was the same as for Test 1 (COE drums nos. H-20, H-21, and H-23). Samples were taken at the following locations:

- Cartridge filter
- Basket strainer
- Feed kettle
- Treated sediment product tank
- Extract product tank.

The cartridge filter was sampled as planned. The sampling plan was modified to include basket strainer sample collection at the end of each pass rather than at the end of each test. The basket strainer filled with particulate matter more rapidly than anticipated. This procedure was repeated for all passes except Pass 9 when the sample volume was too small. Extract samples were taken only at the end of Passes 1, 3, and 10 because the volumes generated with each pass were so small. Treated sediment samples were taken at the end of each of the 10 passes. Grab samples of tap water and harbor water also were taken. Field measurements included pH, weight, and viscosity.

In addition to changes in the sampling plan mentioned for extract and basket strainer sampling, other deviations occurred. For example, the feed material was sampled three times. The second feed sample was obtained after operating personnel added tap water to the feed slurry. This was done to determine the effect water content would have on analyses for PCBs. A third feed sample, "Pass 4 feed" was a mixture of Pass 3 treated sediments taken from product tank no. 1 and overflow collected from product tank no. 2. The second tank needed draining to allow continued operation. The drainage was mostly foam, which was thought to contain material from Passes 1 and 2, as well as Pass 3. Therefore, treated sediment collected from both tanks was composited as a representative sample of the Pass 4 feed.

Sampling logistics were modified at Pass 4 for all future passes because of the foaming problem. Since foaming in both treated sediment tanks was

significant, collection drums were positioned at each. Treated sediments collected from each tank would be composited in a single drum after degassing for each pass. Samples then would be taken from the composite of both tanks. Foaming was a continuous problem throughout Test 2, so treated sediment was left in collection drums overnight to degas for Passes 1, 2, 3, 5, and 8. Samples for Passes 4, 6, 7, 9, and 10 were able to be collected on the same day the run occurred since several daylight hours were available to allow degassing to occur before samples were acquired.

Sampling personnel made the following observations on the physical characteristics of the various wastestreams:

- Treated Sediment. Foaming caused two sampling problems: (1) treated sediment would splatter out of the collection drums and (2) representative samples of liquids and solids could not be drawn with a sample beaker. Analyses for methylene blue active substances (MBAS), total dissolved solids (TSS), and total suspended solids (TSS) subsequently were requested for the tap water, harbor water, and Test 3 feed. Results from these analyses indicated no significant levels of MBAS, TSS, or TDS.

- Extract. Only very small volumes were available for sampling. Laboratory personnel observed particulates in each extract sample.

- Basket Strainer. With each pass the strainer collected one gallon of liquid that contained fibrous solids and large particles.

- Carbon Canister. The carbon canister had not been changed since prior use of the unit at a petroleum refinery.

- Tap Water and Harbor Water. Field personnel conducted an informal field experiment to determine if either the tap or the harbor could be the source of foam in the raffinate. Aeration of aliquots of tap and harbor water produced no foaming. Subsequent methylene blue active substance analyses indicated that neither tap nor harbor water would be a source of foaming agents.

- Cartridge Filter. The cartridge filter was coated with a dark particulate as anticipated.

Test 3

Test 3 was designed to duplicate the first three passes of Test 2 and the test was conducted as such. However, two events occurred that caused some concern about sample integrity: (1) communications among the CF Systems and EPA revealed that the unit had not been decontaminated prior to departing from

a prior demonstration at a petroleum refinery; and (2) potentially contaminated wash water inadvertently got mixed with Pass 1 treated sediments.

The source of sediments was the same as used for Tests 1 and 2 (COE drums nos. H-20, H-21, and H-23). Samples were taken at the following locations:

- Cartridge filter
- Basket strainer
- Feed kettle
- Raffinate product tank
- Extract product tank.

The cartridge filter was sampled at the end of the test. The basket strainer and raffinate were sampled after each of the three passes. Extract was sampled at Passes 1 and 3. Extract sample volumes were small and their flow was erratic at each pass. A sample of feed was collected for methylene blue active substances analyses to determine if the harbor sediment contained agents that caused foaming. Foaming problems persisted through Test 3, so samples were degassed overnight and collected the following day. Field measurements included pH, volume, weight, and viscosity.

Several additional samples were taken to assess the impact of residuals left in the unit from a prior demonstration. Site personnel attempted to wash out these residuals after Test 3, Pass 1 with a refined naphtha fuel. Another sample was taken to determine the effect of the inadvertent addition of wash water to the Pass 2 feed. Each of these events is discussed below.

- Fuel Wash - Test 3 was interrupted to clean the extract product tank (EPT) and the column reboiler (CR). The CR was opened and drained for one hour. The drainage, at first, looked like black water, then some oil appeared before a yellow-orange, frozen material was drained. The mixture was sampled for PCB analysis. The EPT top was then opened and one gallon of Coleman brand fuel, which is a naptha-based product, was added. The EPT sample valve was opened and a sample of the fuel wash was taken. Then 18 gallons of fuel were added to the EPT. The 18-gallon fuel wash was released from the EPT and mixed with the initial wash for sampling and PCB analysis. Subsequent sampling of Pass 3 extract showed that not all of the fuel wash had drained from the EPT, since biphasic characteristics were observed in the Pass 3 extract. Laboratory analyses of the fuel wash and column reboiler

drainage showed that the unit had been accumulating PCBs in the extract product tank and still bottoms tank. Most of the PCBs fed to the unit apparently were not being transferred from the reboiler to the extract tank with each pass. Therefore, closure of a PCB mass balance for each pass based on feed, raffinate, and extract samples is not possible. Similarly, a total mass balance closure for each test is not possible.

- Wash Water - During Pass 2 the hose of the feed pump was placed in a wash water drum and 20 to 30 gallons of wash water were accidentally pumped into the feed kettle. The wash water contained residue from previous samples of treated sediment and feed material. The wash water was mixed with Pass 1 treated sediment and the mixture was sampled as feed to Pass 2. Laboratory analyses showed that this incident had little effect on the demonstration. The Pass 1 treated sediment and Pass 2 feed PCB analyses differed by less than 35 percent.

Test 4

Test 4 was conducted, as planned, on a high PCB concentration (2575 ppm) sediment. Six passes were run in order to ensure that the final treated sediment PCB concentration would be equal to or less than the Tests 2 and 3 feed concentrations. Treatment beyond those concentrations would be inferred by Test 2 and 3 results. Test 4 feed was a composite of sediments taken from COE drums nos. I-11 (one-third) and H-22 (two-thirds). Samples were taken at the following locations:

- Cartridge filter
- Basket strainer
- Feed kettle
- Treated sediment product tank
- Extract product tank.

The cartridge filter was sampled at the end of the test. The basket strainer and treated sediment were sampled at each of the six passes. Extract was sampled at Passes 4 and 6. Treated sediment foaming problems persisted throughout the test and extract volumes continued to be small. Additional samples were shipped as part of the effort to compare analytical results from analysis methods 8080 and 680. Field measurements included pH, volume, weight, and viscosity.

Test 4 also included air sampling and analysis to determine the release of PCBs from sample collection containers to the atmosphere. The potential release of PCBs to the air from the low temperature process was assumed to be insignificant based on the very low vapor pressure of PCBs. Personal air sampling pumps were mounted on the side of the collection containers. During mixing of collection container contents, the container was covered with an aluminum foil and gases evolving from the container were pumped with the personal air sampler through a sorbent tube. This procedure was conducted during the degassing of Passes 1, 2, 3, and 4 treated sediment and Pass 4 extract. Sorbent tubes were shipped for PCB analysis.

Decontamination

System decontamination was conducted with toluene used as the feed. About 100 gallons of toluene were added to the feed kettle, then collected in the treated sediment and extract product tanks. The developer defined a feed volume of 30 gallons, or 10 percent of the extraction system capacity, as sufficient to run a pass through the extractor. Therefore, the equivalent of three single passes of fresh toluene was run through the system (100 gallons/ 30 gallons per pass = 3.3 passes). Toluene wash was collected from the primary and overflow treated sediment tanks. Extract was collected in two batches and contained mostly toluene. All toluene wash samples were analyzed for the purpose of determining the mass of PCBs that had accumulated in the treated sediment and extract product tanks and related equipment. At the end of tank draining, grab samples were taken at the drain valves to establish that the unit had been decontaminated.

The demonstration staging area shown in Figure 5-1 was not contaminated with PCBs that may have been released during testing and sampling. On August 11, 1988, soil samples were taken from 10 locations in the staging area. Samples of soil were taken at zero to six inches of depth. Analytical results showed PCB levels to range from less than 5 to 37 parts per million in the soil. The 10 locations were resampled on October 6, 1988, after CF Systems removed their equipment from the site and SAIC removed debris from the site. Analytical results showed PCB levels to range from less than 0.5 to 5.4 parts per million in the soil. At nine of ten locations, post-demonstration values

were less than predemonstration values. This difference may be the result of variability associated with sampling and analysis.

Debris was collected in 55-gallon drums over the course of the demonstration. The following materials were produced during the demonstration and removed from the staging area by Clean Harbors, Inc.

Number of Drums	Drum Contents
6	Toluene (unit decontamination residue)
6	Toluene rinsewater
2	Naphtha-based fuel product and unit residue
15	Sediments
8	Sediments and water
20	Decontamination water
8	Tyvek suits and water
22	Clothing and gloves
Total = 87	

In addition to these, 14 drums containing harbor sediments obtained from previous COE activities were also removed.

SECTION 6. SAMPLING AND ANALYTICAL PROGRAM

6.1 SAMPLING LOCATIONS

A detailed description of major process equipment and the process flow diagram were presented in Section 3. As discussed, feed sediment is treated for organics removal, then the treated sediment is discharged. PCBs and other organics separated from the feed sediments are discharged as extract. Through a vapor recompression cycle solvent is reused. Minor solvent losses occur due to venting. Vented emissions pass through a carbon canister after the unit is shut down. Other material losses occur as a result of the use of particulate filters that are used throughout the system to protect operating equipment. Materials also exit the unit during system shutdown and cleanout. These materials are residues that have adhered to internal surfaces of tanks, piping, and equipment and that are removed by use of a washing medium, such as toluene or another nonpolar solvent. Figure 6-1 is a simplified diagram of system inputs and outputs. Each system influent, effluent, or loss is defined and described below.

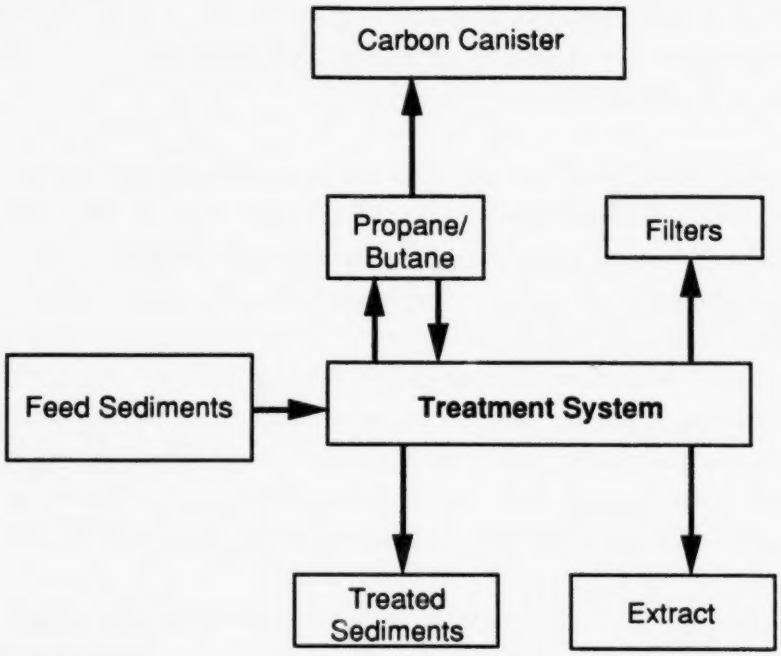


Figure 6-1. System Flow Diagram

Feed Kettle (FK) -- The feed kettle holds a maximum of approximately 80 gallons of slurried sediments. Contents were continuously agitated to provide a fairly homogenous feed. Feed drum contents were continuously agitated and pumped into the feed kettle. Grab samples were taken, during agitation, with a stainless steel ladle. Feed weight was recorded for Tests 2 through 5. Analyses were conducted during Tests 2 through 4 for PCBs, semivolatiles, cadmium, chromium, copper, zinc, lead, oil and grease, total solids, pH, and viscosity. Only PCBs were analyzed during Test 1. Test 5 used only toluene as feed for purposes of decontamination.

Treated Sediment Product Tank (RPT) -- The treated sediment, or raffinate, product tank was accessible at its outlet, a point underneath the trailer. During the demonstration, it was drained and product was collected in either a 55-gallon or an 85-gallon drum. At the conclusion of Tests 2 through 5, the following were determined; PCBs, semivolatiles, cadmium, chromium, copper, zinc, lead, oil and grease, total solids, and pH. Only PCBs were analyzed during Test 1. During Test 4, gases evolving from the sampling containers were sampled using National Institute of Occupational Safety and Health (NIOSH) physical and chemical analytical method 253. Sorbent tubes were used to collect analytes contained in gases emitted from the unit. Decontamination residue was also collected at this point.

Extract Product Tank (EPT) -- The extract product tank was accessible at its outlet, a point underneath the trailer. Extract drained and collected in a covered 5-gallon, stainless steel pail during the demonstration. At the conclusion of Tests 2 through 5, the following were determined: PCBs, semivolatiles, cadmium, chromium, copper, zinc, lead, oil and grease, total solids, and pH. Only PCBs were analyzed during Test 1. During Test 4, gases evolving from the sampling containers were sampled using National Institute of Occupational Safety and Health (NIOSH) physical and chemical analytical method 253. Sorbent tubes were used to collect analytes contained in gases emitted from the unit. Decontamination residue was also collected at this point.

Basket Strainer (S-1) -- The basket strainer prevented oversized feed material from entering the system. For each pass during Tests 2 (except Pass 9) through 4, CF Systems removed the basket strainer. Test 2, Pass 9, was not

sampled because sample volume was not sufficient. Solids were scraped with a stainless steel spoon or spatula from the basket strainer and drained the strainer casing into a stainless steel pail for a weight determination. Solids were shipped for PCB and total solids analyses.

Cartridge Filter (F-2) -- The cartridge filter removed fine particles in the submicron range from the solvent-organics mixture. CF Systems installed cartridge filters, and at the conclusion of each pass removed the filters and scraped solids for a mass determination.

Carbon Canister (CC) -- Propane blowndown from the PCU at the conclusion of the tests and the decontamination procedure was vented through a 20-gallon carbon canister. Following decontamination, CF Systems removed the carbon canister from the treatment system. The carbon canister was emptied with a shovel. At 16 equally spaced distances along the canister height, aliquots were obtained with a stainless steel beaker. The beaker was used to mix the surface of the carbon bed as each aliquot was obtained. The 16 aliquots were composited in a stainless steel pail and then mixed prior to filling sample containers. Sample weight, total solids, and PCB concentration were determined.

Additional planned sampling was conducted as part of the Health and Safety Plan to ensure worker safety and to determine if releases to the environment from process equipment, open tanks, and sample collection containers occurred.

6.2 SAMPLING SCHEDULE

The sampling frequency scheme planned for Tests 2, 3, and 4 is shown in Table 6-1. Sampling was designed to allow determination of: (1) a PCB extraction efficiency with each pass and (2) a mass balance with each pass. Sampling planned for decontamination was similar to that planned for Tests 2, 3, and 4, except that no chemical analyses were conducted for the feed that was composed of toluene.

TABLE 6-1. SAMPLES FOR CF SYSTEMS NEW BEDFORD TESTS 2, 3, AND 4

Sample Location	Sample Frequency(1)	Parameter
Cartridge Filter	Final Pass	PCBs Total Solids
Basket Strainer	Each Pass	PCBs Total Solids
Feed Kettle	First Pass	Volume and Weight PCBs Semivolatiles Cd, Cr, Cu, Zn, Pb Oil and Grease Total Solids, pH Viscosity
Treated Sediment Product Tank	Each Pass	PCBs Volume and Weight
	Final Pass	PCBs Volume and Weight Semivolatiles Cd, Cr, Cu, Zn, Pb Oil and Grease Total Solids, pH
Extract Product Tank	Each Pass	Volume and Weight PCBs Total Solids
	Final Pass	PCBs Volume and Weight Semivolatiles Cd, Cr, Cu, Zn, Pb Oil and Grease Total Solids, pH

Note 1: Test 2 involved 10 passes, Test 3 involved 6 passes, and Test 3 involved 3 passes through the PCU.

6.3 ANALYTICAL METHODS AND PHYSICAL TESTS

The analytical methods selected for the demonstration at New Bedford Harbor included:

- PCB by EPA Method 3550/8080 (EPA 1986)
- PCB by EPA Method 3550/680 (EPA 1983, EPA 1986)
- PCB Extraction Modification by Spittler Screen (Fowler 1987, Spittler 1984)
- Waste Dilution by EPA Method 3580 (EPA 1986)
- Semivolatiles by EPA Method 3550/8270 (EPA 1986)
- Trace Metals by EPA Method 3050/6010 (EPA 1986)
- Particle Size by ASTM Method C-136-84A (ASTM 1984)
- Total Recoverable Oil and Grease by EPA Method 9071 (EPA 1986)
- Percent Solids by EPA Method 160.3 (EPA 1983)
- EP Toxicity (metals) by EPA Method 1310/6010 (EPA 1986)
- pH in Calcareous and Noncalcareous Soils by EPA Method 9045 (EPA 1986)
- Total Metals by EPA Method 3010 (EPA 1986).

All methods were intended to be performed as published. In the event that modifications to the analytical program were required due to matrix constraints, only approved methods were substituted. Any deviations from approved protocol for these methods are discussed in Section 7. The Spittler Screen and a comparison between Analytical Methods 8080 and 680 are discussed below.

Spittler Screen

The Spittler Screen was used to identify the approximate level of PCBs in a sample to aid analysts in choosing dilution factors (Spittler, 1984). Subsequent analyses by EPA Methods were then carried out more efficiently. The Spittler Screen provided rapid analytical turnaround for large volumes of samples to optimize those subject to further analyses. Rapid turnaround of analytical results allowed CF systems to more closely control operating

conditions. This screening procedure was not be used for any critical measurements.

Comparison of Analytical Methods 8080 and 680 for PCBs

Method 8080 is a Resource Conservation and Recovery Act (RCRA) analysis method for determining PCBs as Aroclors. The analysis is conducted by gas chromatography with an electron capture detector (GC/ECD), and quantitation is performed by external standard calibration against one or more Aroclor standards. Pesticide compounds are used as surrogate standards for estimating analytical accuracy.

Method 680 is an analysis method for determining PCBs as congeners (homologous classes based on degree of chlorination) under the Clean Water Act (CWA). The analysis is conducted by gas chromatography with detection by mass spectroscopy (GC/MS), and quantitation is performed by internal standard calibration. Carbon 13-labeled PCB compounds (one from each congener) are used as surrogate standards for estimating analytical accuracy.

Method 8080 was favored as the analysis method for the SITE demonstration at New Bedford Harbor because:

- Method 8080 is a RCRA method and Method 680 is not
- Procedures for extraction of PCBs from sediments have been developed and validated for Method 8080, while Method 680 only addresses water samples
- Because the sediments from New Bedford Harbor were known to contain PCBs, and the PCB content has been thoroughly characterized by COE, the added specificity of GC/MS (Method 680) was not required
- Method 8080 costs less than Method 680.

Method 8080 was finally chosen after a review of the analytical results for Test 4 samples. In Table 6-2, Method 680 analytical results are shown for Test 4, feed and Pass 4 treated sediment samples, and are reported as congener groups rather than the 209 individual congeners. The percent of PCB removed from the feed after the fourth pass is calculated for each congener group. The removal data show that the extraction technology removes less chlorinated

TABLE 6-2. METHOD 680 ANALYTICAL RESULTS FOR TEST 4

PCB Congener Group	Feed (ppm)	Pass 4 Treated Sediment (ppm)	Removal (percent)	Congener Group as a Percentage of the Total Feed (percent)
Mono-	39	0.58	99	Less than 1
Di-	1,150	30	97	13
Tri-	2,800	98	97	32
Tetra-	3,000	130	96	34
Penta	1,400	69	95	16
Hexa-	260	18	93	3
Hepta-	Not detected	12	Not applicable	Less than 1
TOTAL	8,700	350	96	Not applicable

PCBs (e.g., mono- and di-) more efficiently than more chlorinated PCBs (e.g., penta- and hexa-). However, this difference between congener groups is not significant since all calculated removals differ from the mean removal by less than five percent. Furthermore, the monochlorobiphenyl group composes less than one percent of the total mass. Method 8080 was used to measure Aroclors 1242 and 1254, since these represented nearly 70 percent of total PCBs contained in the sediments (COE, 1987).

6.4 PROCESS CONTROL AND FIELD MEASUREMENT DEVICES

Process control and field measurement devices used during the demonstration are listed in Table 6-3. Also shown in Table 6-3 are measurement locations, rationale for measurement, measurement frequency, measurement units, and precision and accuracy. The developer's extractor pressure gages were calibrated against nitrogen gas regulated by an Airco model 0-4000 pressure regulator/gage at 145 and 261 psig. The Airco pressure gage was subsequently calibrated by Calibration Central, Inc., of Herndon, Virginia. The extractor temperature gage was a Sybron Corporation, Bi-Therm model. The feed slurry and cooling water temperature gages were manufactured by Universal Enterprises. The temperature gages were calibrated in an equilibrated mixture of ice and water at 32 degrees F and electrically heated water at 100 degrees F. Feed kettle slurry volume was estimated using a calibration curve developed by CF Systems. A Micro Motion, high-pressure Model D Meter measured solvent flow. The mass flowmeter employed magnetic fields in its operation and was calibrated electronically. Cooling water flow from the system was measured via the classic stopwatch-and-bucket method.

Feed slurry viscosity was measured with a Haake Model Vt-02 cup-and-spindle viscometer. Feed slurry pH was measured by a Corning Model pH 106 pH electrode. Feed, treated sediment, extract, strainer solids, filter residues, and other process materials were weighed on one of two scales. A Howe-Richardson HCR International XL 1000 lbs. x 1/2 lb. scale was used to weigh materials greater than 25 lbs., and a Hanson 25 lbs. x 1 oz. General Household Scale was used to weigh materials less than 25 lbs. The electric power was metered by standard residential-use unit supplied by the local electric utility.

TABLE 6-3. PROCESS CONTROL AND FIELD MEASUREMENTS

Critical Measurement	Measurement Location	Rationale for Measurement	Measurement Frequency	Measurement Units	Precision	Accuracy
PROCESS CONTROL MEASUREMENTS						
Extractor Pressure	E-1 Press. Gage	Verify Operating Conditions	10 min.	psig	1% (1)	5% (2)
Extractor Pressure	E-2 Press. Gage	Verify Operating Conditions	10 min.	psig	1% (1)	5% (2)
Extractor Temperature	E-1 Temp. Gage	Verify Operating Conditions	10 min.	degrees F	0% (1)	0% (2)
Feed Slurry Volume	FK	Verify Operating Conditions	10 min.	gal/min.	(3)	(4)
Feed Slurry Temp.	FK	Verify Operating Conditions	Start of Pass	degrees F	5% (1)	2% (2)
Solvent Flow	Control Room Readout	Verify Operating Conditions	10 min.	lbs/min.	(3)	0.2% (5)
Cooling Water	Outlet Line	Verify Operating Conditions	10 min.	GPM	(3)	0.25% (2)
Viscosity	Feed Drum Immediately Prior to Use	Verify Operating Conditions	Start of Test	dPa.S	(3)	5% (2)
Feed Slurry pH	FK	Verify Operating Conditions	Start of Pass	pH	0.01 units (6)	0.01 units (5)

TABLE 6-3. PROCESS CONTROL AND FIELD MEASUREMENTS (Continued)

Critical Measurement	Measurement Location	Rationale for Measurement	Measurement Frequency	Measurement Units	Precision	Accuracy
MASS INVENTORY MEASUREMENTS						
Feed, Treated Sediment Weight	Feed Weight Scale	Mass Inventory	Start of Pass	lb	1% (1)	1% (2)
Extract Weight	Low Weight Scale	Mass Inventory	End of Test	lb	1% (1)	1% (2)
Strainer	Low Weight Scale	Mass Inventory	End of Pass	lb	1% (1)	1% (2)
Filter Residues	Low Weight Scale	Mass Inventory	End of Test	lb	1% (1)	1% (2)
UTILITIES INPUT MEASUREMENTS						
Electric Power	Input Line to Pilot Unit	Utilities Measurement	During Pass	kw-hr	(6)	(5)
Cooling Water Temperature	Input and Output Streams	Utilities Measurement	10 min.	degrees F	5% (1)	2% (2)

NOTES: (1) Precision as Relative Standard Deviation (RSD).
(2) Accuracy as Relative Percent Difference (RPD).
(3) Precision data not available.
(4) Accuracy data not available.
(5) Accuracy as reported by manufacturer.
(6) Precision as reported by manufacturer.

SECTION 7

RESULTS AND DISCUSSION

7.1 SYSTEM PERFORMANCE

The evaluation criteria established in Section 1.3 for an evaluation of system performance were:

- PCB concentration in sediments before and after treatment
- PCB extraction efficiency with each pass of sediments through the PCU
- Mass balances established for total mass, solids, and PCBs.

These criteria are discussed with respect to analytical results below.

PCB Concentration Reductions

PCB analyses for feed sediments and treated sediment, conducted for samples collected at each pass, are shown in Table 7.1. The data are displayed graphically in Figures 7.1, 7.2, and 7.3. The data show that treated sediment concentrations of 8 ppm are achievable and that as much as 84 percent of the PCB contained in sediment can be removed in a single pass. In Test 2, feed containing 350 ppm of PCB was reduced to 8 ppm after 9 passes through the PCU. In Test 3, a 288 ppm feed was reduced to 47 ppm after just one pass. In Test 4, a 2,575 ppm feed was reduced to 200 ppm after 6 passes. The percent reductions in PCB concentration, based on a comparison of untreated feed to the final pass, for each test were:

Test	Percent Reduction in PCB Concentration	Number of Passes
2	89%	10
3	72%	3
4	92%	6

The data for each test show general reduction trends based on differences between initial feed and final treated sediment concentrations. However, these trends are not consistent on a pass-by-pass basis. For example, PCB concentrations in treated sediments increase at Test 2, passes 4 and 10, and

TABLE 7-1. PASS-BY-PASS PCB CONCENTRATIONS AND REDUCTION EFFICIENCIES

Test Number	Pass Number	PCB Concentration* (ppm)	Pass-by-Pass Concentration Reduction Efficiency (percent)
2	Feed	350	Not Applicable
2	1	77	78
2	2	52	32
2	3	20	62
2	4	66	No Reduction
2	5	59	11
2	6	41	31
2	7	36	12
2	8	29	19
2	9	8	72
2	10	40	No Reduction
3	Feed	288	Not Applicable
3	1	47	84
3	2	72	No Reduction
3	3	82	No Reduction
4	Feed	2,575	Not Applicable
4	1	1000	61
4	2	990	1
4	3	670	32
4	4	325	52
4	5	240	26
4	6	200	17

*PCB data represent feed and treated sediment concentrations.

Figure 7.1
Test 2 PCB Reduction

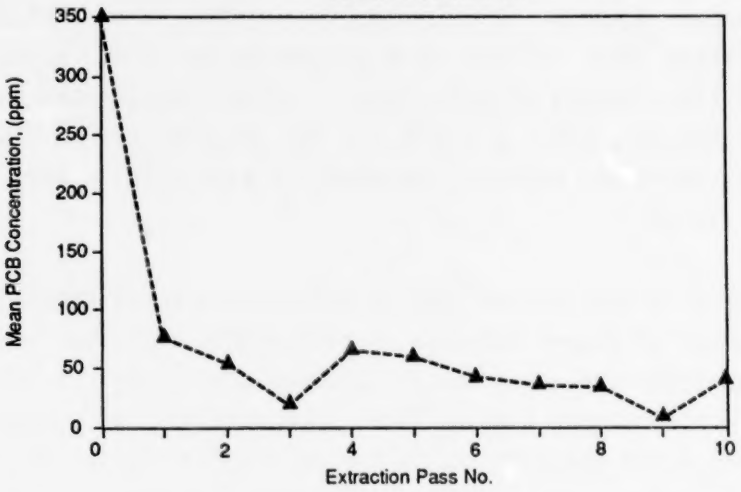


Figure 7.2
Test 3 PCB Reduction

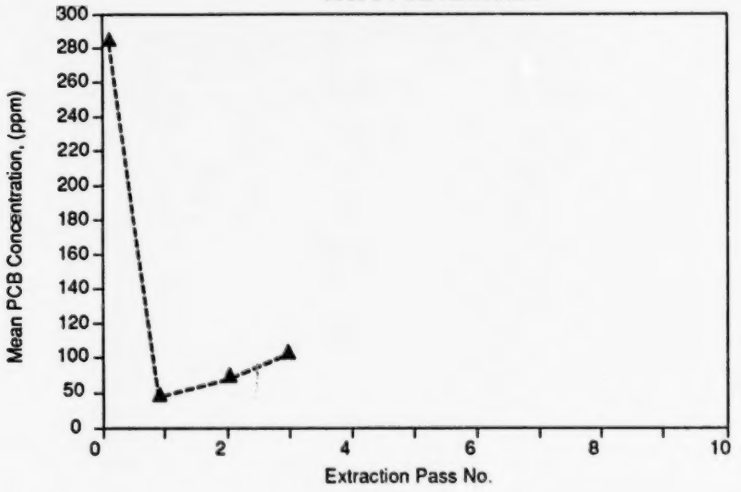
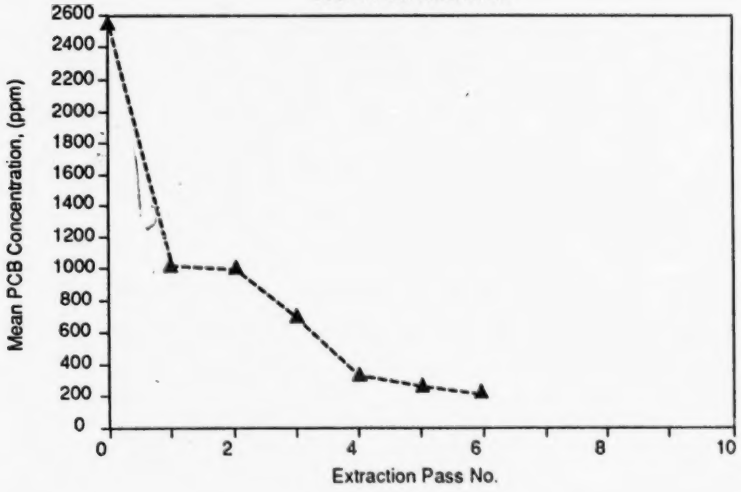


Figure 7.3
Test 4 PCB Reduction



at Test 3, passes 2 and 3. These anomolies are not related to the extraction process. Instead, they reflect cross contamination within system hardware or limited analytical precision and accuracy. Since the treated sediment collection tanks were under pressure, it was not possible to clean out collection hardware and piping. Therefore, a pass-by-pass mass balance could not be established.

Data for each test can be used to construct a curve that shows the potential number of passes required to reduce PCBs in harbor sediments to specific concentrations using the Pit Cleanup Unit (PCU). If data from Test 2, 3, and 4 are displayed side-by-side, such that similar concentrations coincide, then a PCB reduction curve can be plotted. Data are displayed below, side-by-side, so that similar concentrations overlap.

Pass-by-Pass PCB Concentrations

Test 4	Test 3	Test 2
2,575	-	-
1,000	-	-
990	-	-
670	-	-
325	288	350
240	47	77
200	72	52
-	82	20
-	-	66
-	-	59
-	-	41
-	-	36
-	-	29
-	-	8
-	-	40

Based on the presentation of the data in Figure 7-4, it can be construed that harbor sediments containing 2,500 ppm of PCB could be reduced to 100 ppm after 6 passes through the PCU. A level less than 10 ppm may be achievable after 13 passes.

Extraction Efficiency

Pass-by-pass PCB concentration extraction efficiencies are shown in Table 7-1 and are calculated as PCB extracted divided by concentration at the

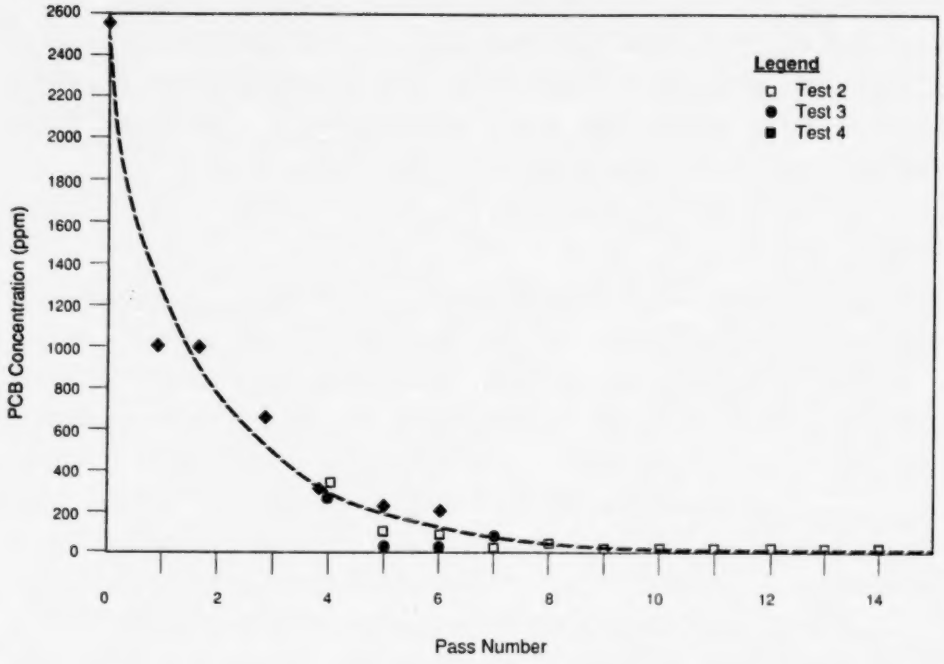


Figure 7.4. Potential Pit Cleanup Unit PCB Reduction

beginning of the pass (multiplied by 100 percent). For each test, the first pass results in efficiencies greater than 60 percent. However, at later passes efficiencies range from negative values to 72 percent. This wide range is the result of cross-contamination of solids retained in the treated sediment subsystem.

Data show that the system irregularly retained and discharged treated sediments. For some passes, as much as 50 percent of the feed was retained in the system. That feed was treated sediment that clung to internal piping and tank surfaces. If discharged with a later pass, the combined discharge could have a higher concentration than feed for the later pass. For example, assume an extraction efficiency of 60 percent, a feed concentration of 350 ppm, and a carry-over of solids from the first pass to the second pass of 25 percent. Then, the treated sediment would contain 77 ppm, instead of 56 ppm if no cross contamination occurred.

The occurrence of cross contamination affects interpretation of each test, but it does not invalidate the fact that treated sediment concentrations as low as 8 ppm were produced. Furthermore, the decontamination procedure showed that PCB, which accumulated in system hardware, was contained in the extract subsystem, not the treated sediment subsystem.

Mass Balances

Total mass, total solids, and total mass of PCBs were determined for various system inputs and outputs for the purpose of establishing a mass balance. Figure 7-5 depicts the inventory sheet used to account for system input and output. Input included feed material and water, although some feed was lost to sampling, sieving, spills, and residuals remaining on the surface of the feed drums. Outputs from the system included samples, spills, container residuals, treated sediment, and residue collected on the basket strainer and cartridge filter. The difference between input and output resulted in either accumulations within the system or unaccounted-for discharges of accumulated material from the system. Appendix A shows mass inventories for each test. The items listed in Appendix A correspond to the depicted in Figure 7-5. Total mass and total solids are shown in the tables as pounds. The mass of PCB is shown as grams.

The amount of material accumulated or the amount of accumulated material discharged are shown for each pass in Table 7-2, "Accumulation or Losses." This term was calculated as total feed minus output. The unit irregularly retained and discharged material throughout Tests 2, 3, and 4. No correlation could be established between the mass inventories and extraction efficiency for each pass. The mass balances for PCB and total solids are discussed in more detail below.

PCB Balance

Table 7-2 illustrates the fate of PCB on a pass-by-pass inventory basis. The system accumulated 15.15 grams during Test 2, 6.71 grams during Test 3, and 42.11 grams during Test 4. Only an approximate PCB balance is possible for Test 1, since Test 1 was a shakedown test only. Approximately 21 grams of

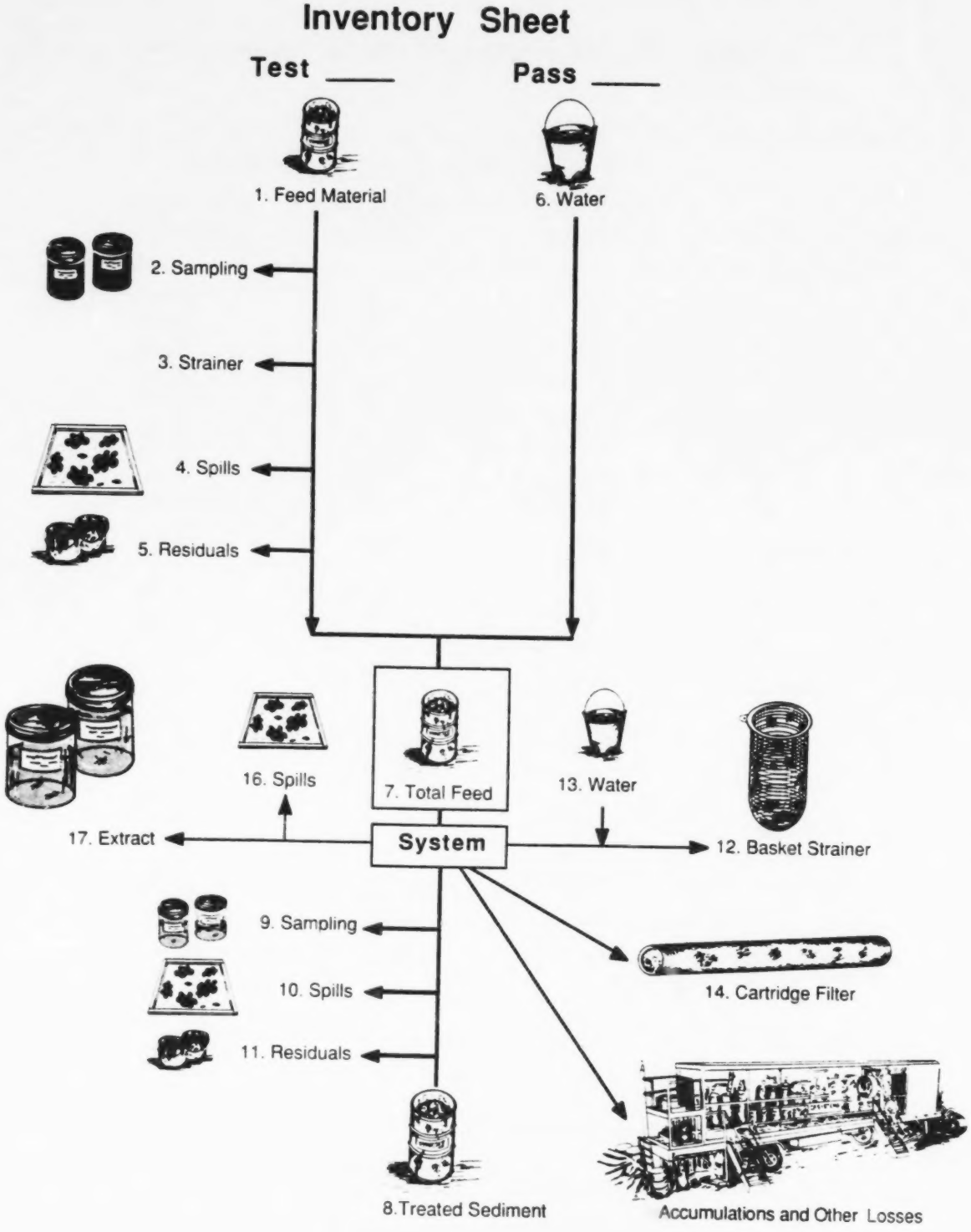


Figure 7.5 Illustrative Inventory Sheet

TABLE 7-2. MASS ACCUMULATION AND LOSS IN THE SYSTEM

Test	Pass	Accumulation (Loss) in the System		
		Total Mass (Pounds)	Total Solids (Pounds)	Total PCBs (Grams)
2	1	122	39	14.21
2	2	55	6	0.70
2	3	(25)	(16)	0.50
2	4	78	32	(0.22)
2	5	22	(6)	(0.07)
2	6	68	3	0.3
2	7	(51)	(1)	0.04
2	8	(7)	(11)	(0.07)
2	9	(16)	(3)	0.29
2	10	9	(3)	(0.54)
	Subtotal	254	40	15.14
3	1	24	(13)	6.28
3	2	58	6	1.42
3	3	29	6	(0.99)
	Subtotal	111	1	6.71
4	1	5	10	37.79
4	2	(83)	(12)	(5.25)
4	3	74	9	8.72
4	4	(80)	4	2.55
4	5	106	6	1.63
4	6	(53)	(3)	(3.33)
	Subtotal	(31)	14	42.11

Note: Parentheses indicate a loss or discharge from the system.

PCB accumulated within the system during Test 1. Thus, total accumulation within the system from Test 1 through Test 4 was about 85 grams (where 84.96 = 15.14 + 6.71 + 42.11 + 21).

Appendix B shows mass balances for the naptha-based fuel and the toluene wash, respectively. The fuel wash, which occurred immediately after the first pass of Test 3, flushed 35 grams of PCB from the extract subsystem. Final system decontamination with toluene wash delivered an additional 151 grams. Total wash output was 35 plus 151, or 186 grams. Ideally, the amount of PCB washed from the system should equal amount accumulated, or

Accumulation - Wash = 0

However, in this case,

85 grams - 186 grams = -101 grams

The amount of PCB washed from the system is shown above to be greater than the amount fed, which raises the possibility that (1) sampling and analytical errors occurred, or (2) the system was contaminated from a previous CF Systems demonstration.

Quality control samples collected during the demonstration indicate the possibility of sampling and analytical error. For example, laboratory precision and accuracy criteria were 20 and 50 relative percent difference, respectively. In addition, quadruplicate grab samples were collected of the Test 3 feed, the Test 4 feed, and the Test 3 treated sediment and the RPD calculated for each set ranged from 12 to 47 percent. In particular, the Test 4 feed had a mean concentration of 2,575 ppm, which dominates all other measurements used in the balance, and it had an RPD of 22. Another possible source of the PCB imbalance was contamination of the PCU from prior use at another site. CF Systems did not decontaminate the unit with toluene prior to this demonstration. CF Systems' standard operating procedures now incorporate decontamination with toluene.

In spite of the calculated PCB imbalance, a positive separation of PCB from the harbor sediments was accomplished. The mass balances in Appendix A show that 81 grams of PCB were contained in sediments fed to the PCU in Tests 2, 3, and 4. Resulting treated sediments contained 4 grams of PCB, which indicates a mass removal efficiency of 95 percent. Decontamination residue data (Appendix B) show that some PCB accumulated in system hardware. However, 91 percent of the PCBs contained in decontamination residues were contained in the extract subsystem. The remaining 9 percent was contained in the treated sediment subsystem hardware.

Basket Strainer, Cartridge Filter, and Carbon Canister

The basket strainer and cartridge filter, which generate residuals that are normally discarded as a waste stream separate from extract and raffinate, did not accumulate a significant PCB mass. The mass balances, shown in Appendix A, show that the accumulation was approximately 2 percent of the PCB mass fed to the system. When compared to PCB removals of 90 percent, this indicates that PCB removal by the basket strainer was not significant. In addition, chemical analysis of the PCB content of filtered solids indicate that the concentration of filtered solids associated with each pass roughly correlated with the treated sediments from the previous pass.

Low pressure propane/butane was vented through the PCU carbon canister at the conclusion of the decontamination procedures. The 285 pounds of activated carbon contained in the canister collected less than 1 gram of PCB. This indicates that air emissions are not significant and PCBs are separated from the solvent when expanded in the PCU.

Total Mass of Solids

The PCU retained and discharged feed material intermittantly throughout the tests. This behavior is demonstrated by tracking the sediment solids. Figures 7-6, 7-7, and 7-8 show the pass-by-pass throughput of solids for Tests 2, 3, and 4. The mass of solids accumulated on a pass-by-pass basis is significant. The flow of solids per pass ranges from 55 percent accumulated to 150 percent discharged. There is no consistent correlation between solids retention and PCB concentration reduction.

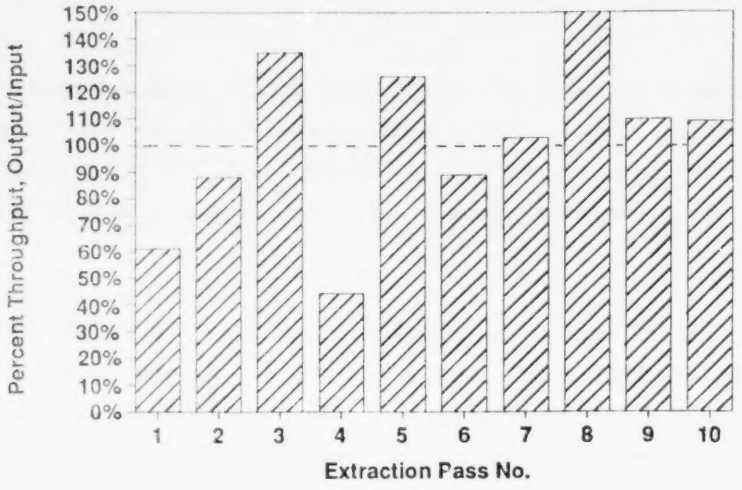


Figure 7.6
Solids Throughput Per Pass
Test #2

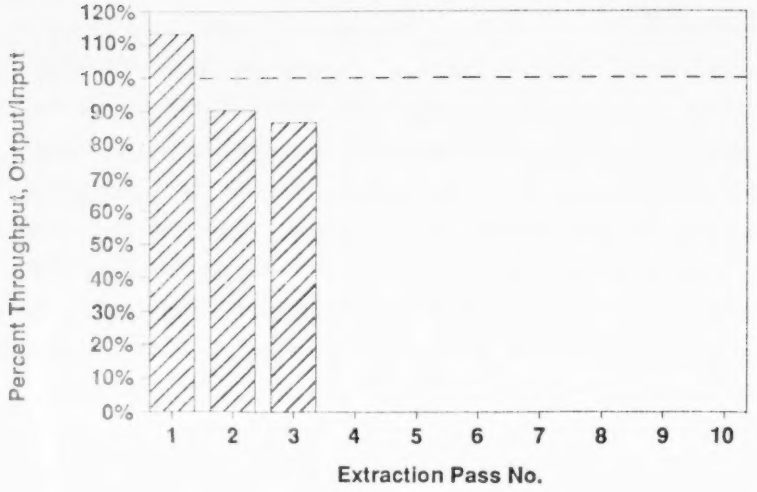


Figure 7.7
Solids Throughput Per Pas
Test #3

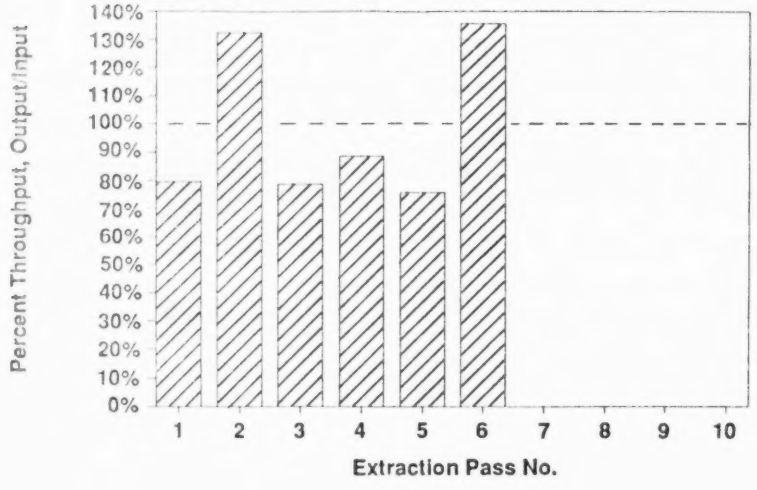


Figure 7.8
Solids Throughput Per Pass
Test #4

During Tests 2, 3, 4, and 5 the system accumulated 302 pounds total mass and 53 pounds total solids. Total mass accumulation represents approximately 4 percent of total mass fed to system during Tests 2 through 5, and total solids accumulation represents about 7 percent of total solids fed to the system.

A total of 3-1/2 tons of solids and water were fed to the unit over the course of 19 passes throughout Test 2, 3, and 4. Of the total, 96 percent was accounted for in the system outputs. Of 789 pounds of solids fed to the system, 93 percent was accounted for in system outputs.

Other Data

Semivolatile Organics

System feed, final treated sediment, and final extract were sampled for base/neutral and acid extractable organics (semivolatiles) during each test for the purpose of (1) characterizing materials for disposal and (2) observing any extraction of semivolatiles. Interpretation of the semivolatiles data, shown in Volume II, is limited for two reasons: (1) the unit contained sludges from a previous demonstration at a petroleum refinery, and (2) a naphtha-based fuel product was added to the unit during Test 3 to clean out the still, extract product tank and related hardware. The following conclusions can be drawn:

- Semivolatiles detected in the toluene wash were also detected in the feed drums, the source being New Bedford Harbor sludge.
- Phenol and 2-methylphenol were found in treated sediments and extracts but were not measured in feed drums, the feed kettle, or toluene washes.
- Test 4 resulted in a reduction of 1,4-dichlorobenzene and pyrene, but chrysene and bis(2-ethylhexyl phthalate) were increased. Similar inconsistencies occur for Test 2 and 3.
- 2-Chlorophenol, 1,3-dichlorobenzene, and benzo(k)fluoranthene were fed to the unit but not detected in any system effluents.

Fate of Metals

A firm conclusion cannot be drawn concerning the fate of metals after each test, since the unit tends to accumulate solids. However, the data in Table 7-3 show that treated sediments metals concentrations generally equal or exceed feed metals concentrations. The data also show that metals were not extracted and discharged in the organics effluent. Metals concentrations in organic extracts were one to two orders of magnitude less than treated sediments.

EP Toxicity

RCRA regulations at 40 CFR 261.24 specify test methods for determining if a solid waste exhibits the characteristic of EP (extraction procedure) toxicity. The maximum concentration of contaminants for the characteristic of EP Toxicity is shown in Table 7-4. Also shown are analytical results for (1) two samples taken from a composite of drummed harbor sediment collected by COE during the waste presampling and (2) a sample of demonstration Test 4, Pass 6 treated sediment. Concentrations for each sample shown are less than the regulatory maximum for the definition of the EP toxicity characteristic.

7.2 OPERATING CONDITIONS

The system specifications that CF Systems requires for normal operation were discussed in Section 3. In this section, observed operating conditions are summarized and operating data are interpreted with respect to treatment efficiency. In tables throughout this section, mean operating data are shown as well as the range of data recorded for each mean value. Generally, the technology accommodated wide ranges of operating conditions, although precise operational control was limited since all controls were manual rather than automatic.

Extraction Pressure

Pressures in both extractors used in the system were fairly stable for all tests. Pressure levels were close to the nominal level of 240 psig. The maximum pressure, 285 psig, was below the 300 psig maximum specification. The minimum pressure, 190 psig, was above the 180 psig minimum specification.

TABLE 7-3. METALS CONTENT OF FEED, TREATED SEDIMENT, AND EXTRACT

Parameter Units	Test 2 Feed	Test 2 Pass 3 Treated Sediment	Test 2 Pass 4 Feed	Test 2 Pass 10 Treated Sediment	Test 2 Pass 10 Extract	Test 3 Feed	Test 3 Pass 3 Treated Sediment	Test 3 Pass 3 Extract	Test 4 Feed	Test 4 Pass 6 Treated Sediment	Test 4 Pass 4 Extract	Test 4 Pass 6 Extract
Cadmium, ppm	35.7	32.5	44.0	42.8	NR(1)	32.0	62.3	6(2)	87.5	120.0	5	5
Chromium, ppm	596	581	761	816	3	525	1020	20	1480	1790	26	31
Copper, ppm	1790	1650	1990	1740	5(2)	1320	2570	6(2)	2650	3700	5	4
Lead, ppm	619	587	792	892	NR(1)	520	1100	NR(1)	1300	1800	35	40
Zinc, ppm	2150	2220	2680	2610	5(2)	1900	3550	8(2)	5370	7260	15	15
Total Residue, %	23.3	18.2	15.0	9.4	NR(3)	19.4	10.3	NR(3)	16.4	5.6	NR(3)	NR(3)

Notes: 1. Not reported, severe matrix effects.

2. Matrix effects indicated.

3. Not reported, insufficient sample volume for analysis method.

TABLE 7-4. EP TOXICITY CHARACTERISTIC OF TREATED AND UNTREATED SEDIMENTS

UNITS (PARTS PER MILLION)

	Composite Sample of Waste Presampling Drums		Treated Sediment	Maximum Concentration Allowable for Characteristics of EP Toxicity
	Sample 1	Sample 2	Test 4, Pass 6	
Arsenic	0.011	0.008	<0.005	5.0
Barium	0.16	0.15	0.36	100.0
Cadmium	0.11	0.12	0.30	1.0
Chromium	0.18	0.098	0.053	5.0
Lead	0.34	0.23	0.16	5.0
Mercury	<0.0002	<0.0002	<0.0002	0.2
Selenium	<0.005	<0.005	<0.02	1.0
Silver	<0.015	<0.015	0.015	5.0

Note: < indicates detected less than the detection limit shown.

Because pressures were so stable, no relationship between extraction efficiency and extractor pressure was apparent.

Feed and Extraction Temperature

Feed and extraction temperatures were stable for Tests 3 and 4. Feed temperatures ranged between 60 and 70 degrees F while extraction temperatures ranged between 60 and 80 degrees F. However, data for Test 2 indicate that feed temperatures fell about 15 degrees F below the minimum specification after pass 5. This caused extraction temperatures to drop, with pass 9 falling 4 degrees F below the minimum specification, 60 degrees F.

The developer attributes much of the fluctuating extraction efficiencies calculated for Test 2 to the low feed temperatures, although other factors were probably important. These factors include cross contamination in the treated sediments collection tank. In addition, reentrainment of solvent in decanter underflows may have caused disproportionately large effects on low concentration sediments. Each factor must be addressed by the developer in the design of a full-scale system.

Feed Flow Rate

The feed flow rate ranged consistently, throughout the tests, from 0.6 to 1.4 gpm. This range compares well with the 0.2 gpm minimum specification and the 1.5 gpm maximum specification.

Solvent Flow Rate

The solvent flow fluctuated outside the minimum specification, 8 lb/min, and the maximum specification, 15 lb/min throughout Tests 2, 3, and 4 as shown in Figures 7-9 through 7-14. Because of this wide variation, it was suspected the flow meter was malfunctioning. In Test 4, an alternative measuring device was used and flow measurements continued to show wide variations, as seen in Figures 7-13 and 7-14.

The variable solvent flows caused the solvent/feed ratio also to fluctuate widely. This ratio was calculated as solvent (lb/min)/feed (gpm)/feed density (lb/gal). The minimum solvent-to-feed ratio specification,

Figure 7-9
Mean Solvent Flowrate
Test 2

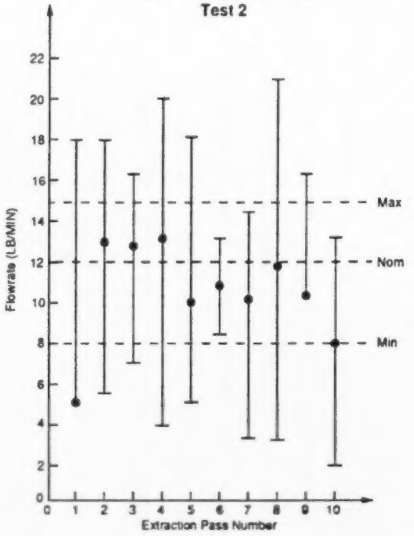


Figure 7-10
Mean Solvent/Feed Ratio
Test 2

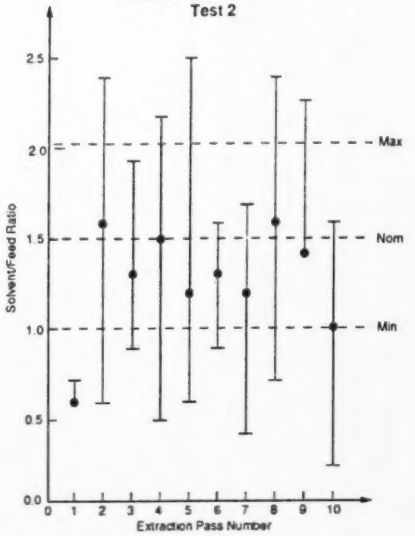


Figure 7-11
Mean Solvent Flowrate
Test 3

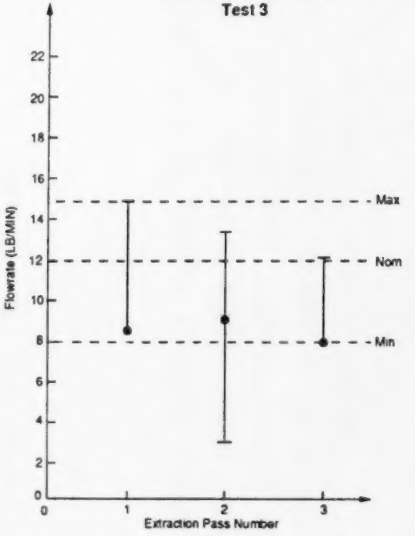
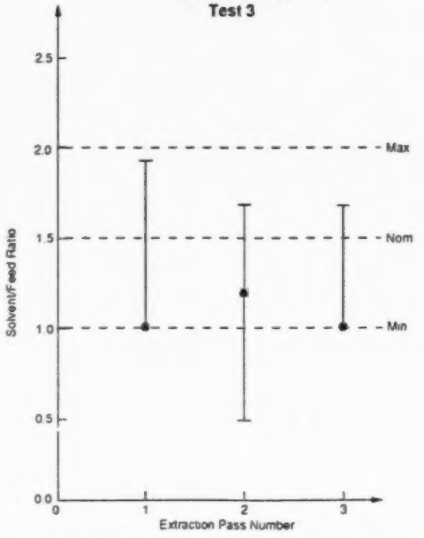
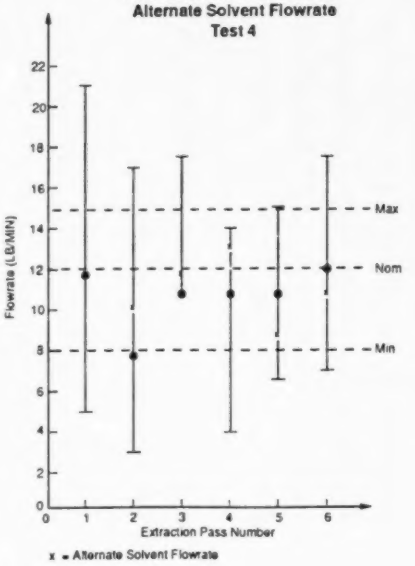


Figure 7-12
Mean Solvent/Feed Ratio
Test 3



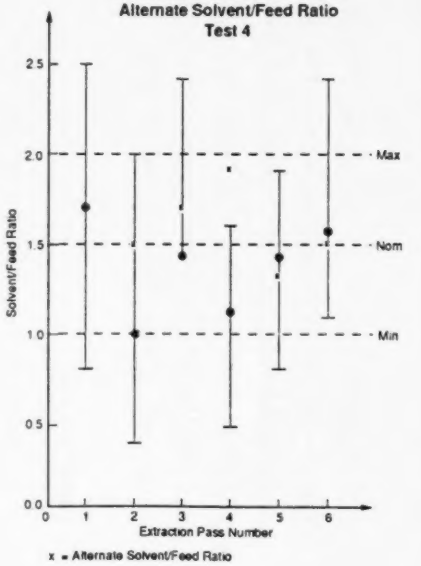
Notes: Flowmeter manufacturer reports 0.2% accuracy.
Mean reported with range of recorded data.

Figure 7-13
Mean Solvent Flowrate Plus
Alternate Solvent Flowrate
Test 4



x = Alternate Solvent Flowrate

Figure 7-14
Mean Solvent/Feed Ratio Plus
Alternate Solvent/Feed Ratio
Test 4



x = Alternate Solvent/Feed Ratio

1.0, was not met on Pass 2 of Test 4 based on mean data. Individual readings frequently exceeded the 1.0 to 2.0 specification range. A pass-by-pass comparison of solvent/feed ratios to extraction efficiencies was attempted but no direct correlation or trend was apparent.

Nonetheless, it is believed that the solvent/feed ratio is a significant factor in process design since the solubility of an organic in liquefied propane-butane is the fundamental basis for the extraction. With higher solvent/feed ratios, the feed is exposed to a larger amount of solvent and extraction efficiency should increase. However, these relationships were not observed, given the available data.

Feed Solids

Feed solids content steadily declined during each test as shown in Figures 7-15 through 7-17. Initial feeds had solids contents ranging from 15 to 22 percent. Final treated sediments ranged from 6 to 11 percent solids. This change is primarily a result of water added to the feed kettle by operating personnel, during each pass. This unnecessary practice caused waste volumes to increase by 33 percent over the course of the demonstration program. Another, but less significant, factor that affected solids content was accumulation of solids in system hardware. The solids mass balance showed that 7 percent of the solids accumulated in the system and were not washed out during decontamination.

Treated sediments that were fed to the unit after Pass 3 of each test, had solids contents below the minimim specification, 10 percent. This dilution of the feed material is believed to affect system performance.

Viscosity and pH

Feed viscosity and pH fell within specifications and did not affect system performance. Viscosities for untreated feed and recycled sediments ranged from 20 to 170 centipoise, well below the 1,000 centipoise maximum specification. This specification was set by the developer only to ensure that the feed would be pumpable. Untreated and recycled sediments had pH values that ranged between 7.3 and 8.5 standard units. This narrow band

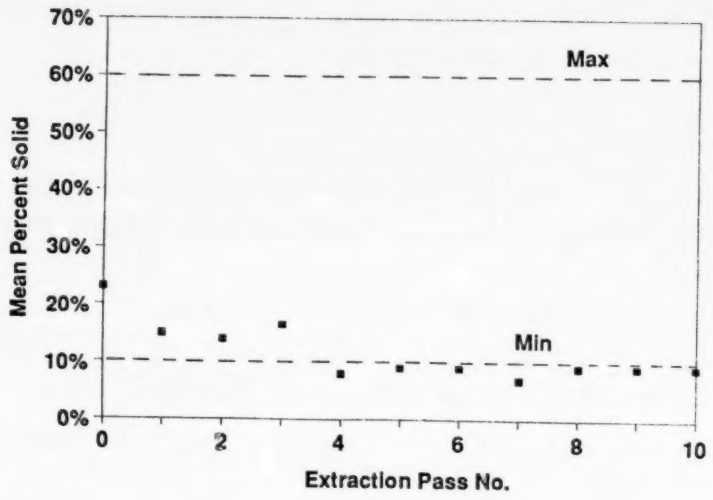


Figure 7.15
Feed/Treated Sediments Solids Concentration
Test #2

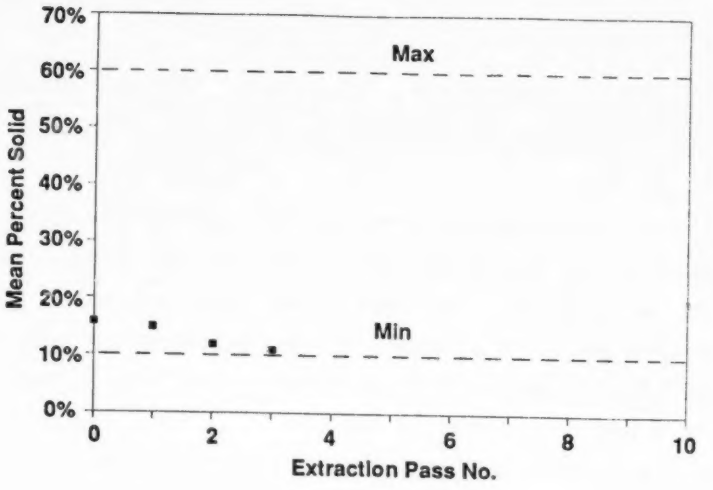


Figure 7.16
Feed/Treated Sediments Solids Concentration
Test #3

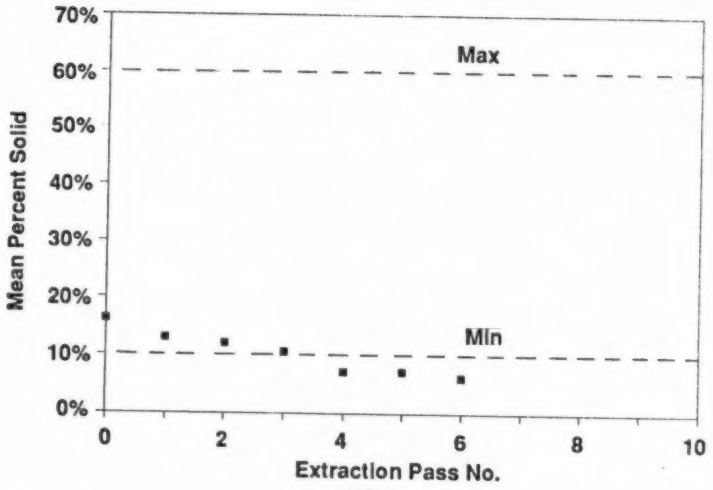


Figure 7.17
Feed/Treated Sediments Solids Concentration
Test #4

fell within the 6 to 12 specification range. The developer established this range to prevent corrosion to PCU hardware.

7.3 DEVELOPER'S GOALS

Since a feasibility study had not been completed for the New Bedford Superfund site, the following treatment goals were set by the developer:

- Test 1 - Shakedown test only.
- Test 2 - Reduce PCB content of a 350 ppm feed by at least 90 percent or to a concentration below 5 ppm after the tenth pass.
- Test 3 - Reduce PCB content of a 288 ppm feed by at least 50 percent or to a concentration below 50 ppm after the third pass.
- Test 4 - Reduce PCB content of a 2,575 ppm feed to the feed levels observed in Test 2 and 3 after 6 passes. (288 ppm was the lower feed of Tests 2 and 3).
- Test 5 - Decontamination process. Achieve effluent concentrations less than 50 ppm in final toluene washes collected from the extract and treated sediment subsystems.

Goals for Tests 3 and 4 were achieved. In Test 3, the Pass 3 treated sediment PCB concentration was 72 percent less than the feed. Thus, the 50 percent reduction goal was met. In Test 4, the pass 6 treated sediment PCB concentration was 200 ppm. Thus, the 288 ppm concentration goal was met. The final treated sediment concentration, at pass 10 for Test 2, was 40 ppm, which meets neither the 5 ppm concentration nor the 90 percent reduction goals. However, a 20 ppm level was observed at pass 3 and 8 ppm was observed at pass 9. Results for Test 5 also fell slightly short of goals for decontamination as discussed in Section 7.4.

These goals were achieved even though (1) operational problems such as foaming and solids retention occurred and (2) the analysis method provided results with a precision of plus or minus 20 percent (measured as relative percent difference).

7.4 HEALTH AND SAFETY MONITORING

During the demonstration of CF Systems' process unit, personnel were potentially exposed to the contaminated harbor sediments. A monitoring program was conducted to determine potential exposures and provide a basis for selection of proper personal protective equipment. Several types of portable monitoring equipment were used during the various phases of the field investigations, including:

- Portable Organic Vapor Analyzer (Century OVA)
- Portable Photoionization Meter (HNu)
- Combustable gas/oxygen/hydrogen sulfide meters (MSA and Enmet-Tritector)
- Detector tubes and sampling pump (Sensidyne-Gastec)
- Personal air sampling pumps (Dupont-P200).

It was suspected that some level of organic vapors would be encountered, particularly when drums containing contaminated sediments were first opened during the feed preparation phase. Continuous monitoring using both the OVA and HNu instruments was conducted while the drums were being opened. These instruments detected a slight elevation above background levels of organic vapor immediately upon opening the drums. The levels returned to background levels within a few seconds. No measurable levels of hydrogen sulfide or combustible gas were encountered while opening the drums or handling the sediments during the feed preparation phase.

During the various test runs of the extraction unit at the New Bedford site, organic vapors, PCBs, combustible gases, and hydrogen sulfide were monitored. The OVA and HNu meters were used to monitor for organic vapors at all work stations on the extraction unit, while CF Systems and SITE personnel monitored process equipment. The OVA also was used as a survey meter on the process equipment to search for possible fugitive emissions from the equipment. All measurements indicated that organic vapor levels remained in the range of background levels. Two portable combustible gas meters were used to check for elevated levels of propane during the equipment shakedown period and for spot testing during the demonstration. The pilot unit also contained

two integral combustible gas detectors located on either end of the unit. During the normal extraction process, combustible gas readings remained at background levels. However, while treated sediment and extract samples were collected, the combustible gas meters indicated that levels exceeding only 20 percent of the lower explosive limit for propane were encountered. These episodes of elevated propane levels generally lasted for less than 60 seconds and subsided rapidly depending on the length of time sampling occurred and the strength of the wind at the time.

Sampling was conducted using personal sampling pumps and 150-mg charcoal tubes and florosil tubes to determine personal exposures to organic vapors and PCBs, respectively. All air sample results indicated that, if present, organic vapors and PCB levels were present only at levels below the detection limits for the analytical methods. No measurable levels of hydrogen sulfide were detected using either detector tubes or portable monitoring devices.

Treated sediment and extract subsystems were decontaminated with toluene. The final concentration of PCB contained in the treated sediment subsystem toluene wash was 34 ppm, which was below the decontamination goal of 50 ppm. The final concentration of PCB contained in extract subsystem toluene wash was 60 ppm, which slightly exceeded the decontamination goal of 50 ppm. Staging area soils were not affected by any leaks or emissions that may have occurred during the duration of the demonstration as discussed in Section 5.3.

7.5 EQUIPMENT AND MATERIAL HANDLING PROBLEMS

Equipment and material handling problems occurred throughout the demonstration, as described in Section 5. While these problems did not impede achievement of the developer's treatment goals, they could impact the economic performance of a full-scale commercial system. Some problems were anticipated since relatively small volumes of sediments were batch-fed to a unit that was designed for continuous operation. The nominal capacity of the unit is 700 gallons per day, but only 50 to 100 gallons per day were batch-fed during shakedown on tests 2, 3, and 4. Consequently, the unit irregularly discharged and retained solids with each pass.

Previous use of the unit affected interpretation of semivolatiles data and may have contributed to imbalance of the PCB inventory. Internal surfaces of extract collection hardware collected PCBs as evidenced by mass balances. In addition, Test 3 was interrupted and viscous oils were found accumulating in extract subsystem hardware. PCBs are soluble in oil, which coated the internal surfaces of system hardware. The amount of oil that can coat internal piping and collection tanks could be significant. For example, assume (1) a hardware surface area of 10 square meters, (2) a coating thickness of 0.1 millimeters, and (3) an oil density of 1.0 grams/cubic centimeter. This is equivalent to 100 grams of oils that cling to the internal surfaces of extract subsystem hardware. As a result of this demonstration, CF Systems now requires more rigorous decontamination procedures for the PCU.

Solids were observed in extract samples that were expected to be solids-free. This indicates poor performance or failure of the cartridge filter. An alternative type of filter should be investigated by the developer.

Low-pressure dissolved propane and butane caused foaming to occur in the treated sediment product tanks. This hindered sample collection and caused frequent overflow of treated sediment to a secondary treated sediment product tank. CF Systems states that design of a commercial-scale unit will allow release of solvent entrained in the treated sediment and elimination of the foaming problem.

7.6 DATA QUALITY ASSURANCE

All field sampling and laboratory analyses were accompanied by a program of quality assurance/quality control (QA/QC) checks designed to assess the validity of the sampling and analysis effort. This program was designed to ensure that the samples are representative, and that the analytical data accurately describes the characteristics and concentrations of constituents in the samples. This QA/QC program is outlined in the approved Quality Assurance Project Plan (QAPP).

Technical Systems Reviews

EPA conducted a technical systems review of the field activities during the dress-rehearsal for the demonstration. This field audit verified that the sampling procedures used would result in samples that met the requirements of the QAPP, and resulted in a satisfactory rating, the highest rating achievable.

EPA also conducted a technical systems review of each of the laboratories involved in the analysis of samples from the CF Systems Demonstration project, examining the laboratory's procedures for sample storage, preparation, analysis, and documentation. While some concerns were identified during each of these reviews, these concerns were addressed to the satisfaction of the reviewer before analyses were continued.

Data Review and Validation

In order to assess the validity of the measurement data, the QC data generated with the environmental data were evaluated with respect to the project quality assurance objectives defined in the QAPP, as well as the specific quality control requirements of the analysis methods used. These laboratory QC data are presented in Volume II. The evaluation of the QC data was accomplished through review of:

- Completeness of analytical reporting
- Analytical holding times
- Target analyte identification criteria
- Tentatively identified compound (TIC) identification criteria
- Calibration frequency and acceptance criteria
- Presence and contamination of method blanks
- Surrogate compound recovery
- Presence and conformance with acceptance criteria of matrix spike, matrix spike duplicate, and duplicate analyses.

Evaluation and Qualification of Measurement Data

The following sections present brief summaries of the findings of the data review and validation, by analyte class.

Polychlorinated Biphenyls

Method 8080 Analyses

Fifty-three sediment samples were analyzed for PCBs from Tests 1 through 5, either as feed stock, treated sediments, or decontamination residues. Ninety-five percent of the recoveries calculated from the matrix spike/matrix spike duplicate (MS/MSD) sample pairs analyzed with these samples were within the project quality assurance objectives defined in the QAPP indicating acceptable accuracy for the analysis of these samples.

Forty-eight percent of the surrogate recoveries calculated from these samples exceeded the acceptance criteria. Because the surrogate compound used for these samples (dibutylchlorendate) is not a polychlorinated biphenyl (PCB), the the matrix spike data are more indicative of the accuracy of analysis for PCBs in these samples.

Only twenty-one percent of the relative percent differences (RPDs) calculated between the MS/MSD sample pairs were within the defined aceptance criteria, indicating that the established precision criteria (plus or minus 20 percent) were too ambitious. The average RPD calculated between MS/MSD pairs was 47 percent. EPA analysis method 8080 QC acceptance criteria show RPDs greater than 60 percent for PCB 1242 and PCB 1254 (EPA, 1986).

None of the method blanks associated with these samples were contaminated with PCBs.

The results of analyses of PCBs in extract samples were not used as part of the demonstration evaluation and have not been included as part of this QA evaluation.

Collectively, these data show that the analysis of PCBs in sediments for Tests 1 through 5 are sufficiently accurate and precise to allow for engineering assessment of the efficacy of this Demonstration.

Method 680 Analyses

The recoveries of congeners spiked into samples analyzed by method 680 were outside of the interim acceptance criteria for monochlorobiphenyl through tetrachlorobiphenyl isomer groups in one MS/MSD sample pair (Test 1). The RPDs calculated for this sample pair were outside of the interim acceptance criteria for mono- and dichlorobiphenyl. The surrogate recoveries for this Test 1 analysis were also outside of the acceptance criteria for the monochlorobiphenyl isomer group. In Test 4 analyses, the accuracy and precision problems were not the case. Therefore, the data presented are insufficient for evaluation of the accuracy and precision of analysis for the less chlorinated congeners. Based on this information, the analytical data for the more highly chlorinated isomers should, however, be of acceptable accuracy and precision.

Spittler Analyses

The data from the Spittler screening analyses were used for decisions in the field, but were not the basis for any conclusions drawn for the final report. These data were, therefore, not included in the data review and validation process.

Base/Neutral and Acid Extractable Compounds (BNAs)

Both sediment and oil samples were analyzed for BNAs. The recovery of one or more compounds in the each of the MS/MSD samples analyzed with the sediment samples were outside of the established acceptance criteria. In addition, each of the sediment samples was spiked with surrogate compounds. The recovery of these surrogate compounds were within acceptance criteria for 20 of the 26 samples. While these data are in apparent conflict, they cast doubt over the acceptability of the analytical accuracy. The relative percent difference (RPD) calculated between analyses of at least one compound in each of the MS/MSD pairs exceeded the acceptance criteria specified in the analytical method, indicating a generally unacceptable degree of analytical precision.

No MS/MSD samples were analyzed with the oil samples analyzed for BNAs, therefore, the recovery of matrix spike compounds cannot be used to evaluate the analytical accuracy. While the samples were spiked with surrogate

compounds, the recoveries cannot be calculated in most of the samples because of dilution effects. There is, therefore, an inadequate basis for evaluation of analytical accuracy and precision.

The only target analytes detected in the method blanks associated with these analyses are common plasticizers (phthalic acid esters), which may have been introduced into the samples during field or laboratory activities.

The BNA data should be considered as qualitative, rather than quantitative, based on conflicting or inadequate information available to evaluate analytical accuracy, as well as poor precision of analysis.

Volatile Organic Analytes (VOAs)

The recoveries calculated from the MS/MSD sample analyzed with the sediment samples are within acceptance criteria, as are the recoveries calculated from the surrogate compound spikes. These data indicate an acceptable degree of accuracy for this noncritical measurement.

The RPDs calculated between the spike compounds in the MS/MSD pair are within the acceptance criteria specified in the analysis method, indicating acceptable precision for the analysis of VOAs in sediment samples.

The method blank associated with these samples show that the samples may have been contaminated with low concentrations of methylene chloride, a common laboratory contaminant. The data from analysis of sediment samples for VOAs are not qualified in any way, and should be regarded as quantitative.

Metals analyses were performed on sediment grab samples, composite samples and oil samples.

The recoveries calculated from one of the two MS/MSD sample pairs analyzed with the sediment grab samples are outside of acceptance criteria for many of the target analytes; however, those calculated from the other MS/MSD pair are acceptable. These conflicting data do not provide sufficient information for the evaluation of analytical accuracy. The RPDs calculated

between one MS/MSD sample pair, and duplicate sample pairs, are within acceptance criteria, indicating an acceptable level of analytical precision for these analyses. The method blanks associated with these samples demonstrate that the samples were not contaminated in the laboratory with the target analytes. Because of the lack of information for evaluation of accuracy, these data should be regarded as qualitative.

The recoveries calculated from the MS/MSD samples analyzed with the composite sediment samples, and the RPDs calculated between the MS/MSD sample pairs and duplicate sample pairs, indicate an acceptable level of analytical accuracy and precision for these analyses. The method blanks associated with these samples demonstrate that the samples were not contaminated in the laboratory with the target analytes.

All oil samples were analyzed for metals by the method of standard additions (MSA). Significant matrix interferences were reported for the majority of these samples. The RPDs reported between the analysis of a duplicate sample pair were within acceptance criteria for two of the five analytes of interest. The method blank associated with these samples demonstrates that the samples were not contaminated in the laboratory with the target analytes. Together, these data indicate that the results from metals analyses in oil samples have an unacceptable level of accuracy and precision, and should be regarded as qualitative.

In addition to the total metals analyses, sediment samples were analyzed for the characteristic of Extraction Procedure Toxicity (EP Tox). The recoveries calculated from the MS sample prepared with these samples are within acceptance criteria for six of the eight target analytes. The RPDs calculated between two duplicate sample pairs are within acceptance criteria for some target analytes, outside of acceptance criteria for others, and cannot be evaluated for the remaining analytes due to nondetectable concentrations in the samples. The method blanks associated with these samples demonstrate that the samples were not contaminated in the laboratory with the target analytes. Together, these data indicate an acceptable degree of accuracy and an unacceptable degree of precision for these analyses. The data should, therefore, be regarded as qualitative.

Total Residue

The recoveries calculated from control samples analyzed for total residue, along with the sediment samples, are within acceptance criteria, as are the RPDs calculated between 99 percent of the duplicate samples analyzed. These data indicate acceptable accuracy and precision for these analyses.

The data from analysis of sediment samples for Total Residue are not qualified in any way, and should be regarded as quantitative.

Total Oil and Grease

Twenty-five percent of the recoveries calculated from the analyses of control samples for total oil and grease, and fifteen percent of the RPDs calculated between replicate analyses, were outside of the acceptance criteria. About one third of the method blanks associated with these samples were found to have detectable concentrations of oil and grease, demonstrating the potential for low-level contamination of the samples in the laboratory.

Cyanide

The recovery calculated from a control sample analyzed along with sediment samples for cyanide is within acceptance criteria. The recovery of cyanide from a post-digestion spike sample was, however, outside of acceptance criteria, providing conflicting information for the evaluation of analytical accuracy. The RPD calculated from the analysis of a replicate pair is within acceptance criteria, indicating acceptable analytical precision.

The data from analysis of sediment samples for cyanide should be regarded as qualitative, based on conflicting evidence for the evaluation of accuracy.

Total Dissolved Solids

The recovery from a spiked control sample analyzed with water sample for total dissolved solids is within acceptance criteria, indicating acceptable accuracy. Because no replicate pairs of samples were analyzed for total dissolved solids, the analytical precision of this noncritical measurement cannot be evaluated.

The TDS data should be considered as qualitative, rather than quantitative, based on inadequate information to evaluate the analytical precision.

Total Suspended Solids

No quality control check sample or replicate sample was analyzed with the water samples analyzed for total suspended solids, therefore the analytical accuracy and precision of this measurement cannot be evaluated.

The TSS data should be considered as qualitative, rather than quantitative, based on inadequate information to evaluate the analytical accuracy and precision.

pH

No quality control check samples were prepared for the measurement of pH in sediment samples, therefore the analytical accuracy of this measurement cannot be evaluated. The RPD calculated between pH measurements made on a replicate sample pair are within acceptance criteria; however, the frequency of replicate pair analysis was insufficient.

The pH data should be considered as qualitative, rather than quantitative, based on inadequate information to evaluate the analytical accuracy and precision.

SECTION 8

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APPENDIX A

MASS INVENTORIES FOR TESTS 2, 3, AND 4

TOTAL MASS BALANCE (Lbs)
TEST #2

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	483.50	367.15	328.46	351.54	296.50	305.00	259.00	321.25	347.00	378.00	3437.40
2 (Sampling)	0.00	3.09	0.00	1.13	0.00	0.00	5.13	0.00	0.00	0.00	9.35
3 (Strainer)	4.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.63
4 (Spills)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 (Residuals)	88.00	2.88	1.33	2.86	1.56	0.31	0.18	0.43	0.76	0.76	99.07
6 Water	120.12	41.75	20.57	61.88	49.06	31.32	29.19	34.36	22.25	22.31	412.81
7 Total Feed	510.99	402.93	347.70	389.43	344.00	336.01	282.88	355.18	368.49	399.55	3737.16
8 Raffinate	367.15	328.46	351.54	296.50	305.00	259.00	321.25	347.00	378.00	346.75	3300.65
9 Sampling	0.00	2.74	9.53	5.19	6.09	0.00	4.44	5.77	5.77	31.81	71.34
10 Spills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11 Residuals	0.00	0.00	2.75	1.50	2.25	0.75	0.00	1.25	1.00	0.00	9.50
12 Basket Strainer	22.00	17.01	8.75	8.50	8.38	8.19	8.25	8.25	0.00	8.94	98.27
13 (H2O)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14 Cartridge Filter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.81	2.81
15 Extract	0.06	0.05	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.61
16 Spills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Output	389.21	348.26	372.76	311.69	321.72	267.94	333.94	362.27	384.77	390.62	3483.18
Accumulation & Other Losses	121.78	54.67	-25.06	77.74	22.28	68.07	-51.06	-7.09	-16.28	8.93	253.98

TOTAL SOLIDS BALANCE (lbs)
TEST #2

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	111.21	55.07	45.98	58.00	23.72	27.45	23.31	22.17	31.58	34.02	432.51
2 (Sampling)	0.00	0.46	0.00	0.19	0.00	0.00	0.46	0.00	0.00	0.00	1.11
3 (Strainer)	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06
4 (Spills)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 (Residuals)	12.32	0.43	0.19	0.47	0.12	0.03	0.02	0.03	0.07	0.07	13.75
6 Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 Total Feed	97.82	54.18	45.80	57.35	23.60	27.42	22.83	22.14	31.51	33.95	416.59
8 Raffinate	55.07	45.98	58.00	23.72	27.45	23.31	22.17	31.58	34.02	31.21	352.51
9 Sampling	0.00	0.38	1.57	0.42	0.55	0.00	0.31	0.53	0.52	2.86	7.13
10 Spills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11 Residuals	0.00	0.00	0.45	0.12	0.20	0.07	0.00	0.11	0.09	0.00	1.05
12 Basket Strainer	4.18	1.36	1.66	1.11	1.42	1.06	1.16	0.91	0.00	1.25	14.11
13 (H2O)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14 Cartridge Filter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	1.60
15 Extract	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16 Spills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Output	59.[illegible]	47.73	61.69	25.36	29.63	24.44	23.63	33.12	34.63	36.92	376.41
Accumulation & Other Losses	38.57	6.45	-15.89	31.99	-6.03	2.98	-0.80	-10.99	-3.12	-2.97	40.19

TOTAL PCB BALANCE (Grams)

TEST #2

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	17.67	1.93	1.09	0.53	0.71	0.74	0.43	0.36	0.42	0.12	23.99
2 (Sampling)	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03
3 (Strainer)	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
4 (Spills)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 (Residuals)	0.95	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98
6 Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 Total Feed	16.55	1.89	1.08	0.52	0.71	0.73	0.42	0.36	0.41	0.12	22.81
8 Raffinate	1.93	1.09	0.53	0.71	0.74	0.43	0.36	0.42	0.12	0.57	6.89
9 Sampling	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.05	0.12
10 Spills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11 Residuals	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
12 Basket Strainer	0.41	0.10	0.02	0.01	0.02	0.00	0.01	0.01	0.00	0.01	0.61
13 (H2O)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14 Cartridge Filter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15 Extract	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
16 Spills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Output	2.34	1.20	0.57	0.74	0.77	0.44	0.38	0.44	0.12	0.66	7.66
Accumulation & Other Losses	14.21	0.70	0.51	-0.22	-0.07	0.30	0.04	-0.07	0.29	-0.54	15.15

TOTAL MASS BALANCE (Lbs)

TEST #3

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	460.75	563.00	482.30								1506.05
2 (Sampling)	40.74	4.64	0.00								45.38
3 (Strainer)	0.00	0.00	0.00								0.00
4 (Spills)	0.00	0.00	0.00								0.00
5 (Residuals)	0.87	3.26	130.55								134.68
6 Water	88.86	0.00	0.00								88.86
7 Total Feed	508.00	555.10	351.75								1414.85
8 Raffinate	465.00	482.30	310.75								1258.05
9 Sampling	5.95	5.81	0.00								11.76
10 Spills	0.00	0.00	0.00								0.00
11 Residuals	2.75	0.80	0.00								3.55
12 Basket Strainer	9.75	8.44	9.37								27.56
13 (H2O)	0.00	0.00	0.00								0.00
14 Cartridge Filter	0.00	0.00	1.37								1.37
15 Extract	0.19	0.00	0.94								1.13
16 Spills	0.00	0.00	0.00								0.00
Output	483.64	497.35	322.43								1303.42
Accumulation & Other Losses	24.36	57.75	29.32								111.43

TOTAL SOLIDS BALANCE (Lbs)
TEST #3

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	72.94	67.56	57.88								198.37
2 (Sampling)	6.45	0.56	0.00								7.01
3 (Strainer)	0.00	0.00	0.00								0.00
4 (Spills)	0.00	0.00	0.00								0.00
5 (Residuals)	0.14	0.39	15.67								16.19
6 Water	0.00	0.00	0.00								0.00
7 Total Feed	66.35	66.61	42.21								175.17
8 Raffinate	69.75	57.88	34.18								161.81
9 Sampling	0.89	0.70	0.00								1.59
10 Spills	0.00	0.00	0.00								0.00
11 Residuals	0.41	0.10	0.00								0.51
12 Basket Strainer	3.90	1.52	1.69								7.11
13 (H2O)	0.00	0.00	0.00								0.00
14 Cartridge Filter	0.00	0.00	0.74								0.74
15 Extract	0.00	0.00	0.00								0.00
16 Spills	0.00	0.00	0.00								0.00
Output	74.96	60.19	36.61								171.75
Accumulation & Other Losses	-8.61	6.42	5.60								3.42

TOTAL PCB BALANCE (Grams)

TEST #3

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	9.58	3.44	1.89								14.90
2 (Sampling)	0.85	0.03	0.00								0.88
3 (Strainer)	0.00	0.00	0.00								0.00
4 (Spills)	0.00	0.00	0.00								0.00
5 (Residuals)	0.01	0.02	0.51								0.55
6 Water	0.00	0.00	0.00								0.00
7 Total Feed	8.72	3.39	1.38								13.48
8 Raffinate	1.49	1.89	1.29								4.67
9 Sampling	0.02	0.02	0.00								0.04
10 Spills	0.00	0.00	0.00								0.00
11 Residuals	0.01	0.00	0.00								0.01
12 Basket Strainer	0.20	0.05	0.06								0.31
13 (H2O)	0.00	0.00	0.00								0.00
14 Cartridge Filter	0.00	0.00	0.00								0.00
15 Extract	0.08	0.00	1.03								1.11
16 Spills	0.00	0.00	0.00								0.00
Output	1.80	1.97	2.38								6.15
Accumulation & Other Losses	6.92	1.42	-1.00								7.33

TOTAL MASS BALANCE (Lbs)

TEST #4

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	333.25	279.75	348.75	298.00	360.20	256.00					1875.95
2 (Sampling)	33.86	0.00	0.00	0.00	0.00	0.00					33.86
3 (Strainer)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
4 (Spills)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
5 (Residuals)	0.56	0.68	0.94	0.00	1.20	0.26					3.64
6 Water	0.00	39.32	39.14	0.00	16.70	22.42					117.58
7 Total Feed	298.83	318.39	386.95	298.00	375.70	278.16					1956.03
8 Raffinate	279.75	348.75	297.50	360.20	256.00	319.25					1861.45
9 Sampling	5.48	6.57	6.76	4.76	4.23	0.00					27.80
10 Spills	0.00	0.00	0.00	0.00	0.00	0.00					0.00
11 Residuals	0.00	37.75	1.00	3.75	1.75	0.50					44.75
12 Basket Strainer	8.25	8.32	8.06	8.25	8.00	7.81					48.69
13 (H2O)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
14 Cartridge Filter	0.00	0.00	0.00	0.00	0.00	2.00					2.00
15 Extract	0.00	0.00	0.00	1.00	0.00	1.38					2.38
16 Spills	0.00	0.00	0.00	0.00	0.00	0.00					0.00
Output	293.48	401.39	313.32	377.96	269.98	330.94					1987.07
Accumulation & Other Losses	5.35	-83.00	73.63	-79.96	105.72	-52.78					-31.04

TOTAL SOLIDS BALANCE (Lbs)

TEST #4

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	53.99	36.37	41.85	31.29	26.11	18.43					208.04
2 (Sampling)	5.49	0.00	0.00	0.00	0.00	0.00					5.49
3 (Strainer)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
4 (Spills)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
5 (Residuals)	0.09	0.09	0.11	0.00	0.09	0.02					0.40
6 Water	0.00	0.00	0.00	0.00	0.00	0.00					0.00
7 Total Feed	48.41	36.28	41.74	31.29	26.02	18.41					202.15
8 Raffinate	36.37	41.85	31.24	26.11	18.43	19.95					173.95
9 Sampling	0.71	0.79	0.71	0.35	0.30	0.00					2.86
10 Spills	0.00	0.00	0.00	0.00	0.00	0.00					0.00
11 Residuals	0.00	4.53	0.11	0.27	0.13	0.03					5.06
12 Basket Strainer	1.40	0.83	0.81	1.03	0.88	0.55					5.50
13 (H2O)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
14 Cartridge Filter	0.00	0.00	0.00	0.00	0.00	0.38					0.38
15 Extract	0.00	0.00	0.00	0.00	0.00	0.00					0.00
16 Spills	0.00	0.00	0.00	0.00	0.00	0.00					0.00
Output	38.48	48.00	32.86	27.76	19.74	20.91					187.76
Accumulation & Other Losses	9.93	-11.72	8.88	3.53	6.28	-2.50					14.40

TOTAL PCB BALANCE (Grams)
TEST #4

ITEM	PASS # 1	2	3	4	5	6	7	8	9	10	TOTALS
1 Feed Material	62.56	16.51	18.81	9.54	3.85	2.01					113.28
2 (Sampling)	6.36	0.00	0.00	0.00	0.00	0.00					6.36
3 (Strainer)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
4 (Spills)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
5 (Residuals)	0.11	0.04	0.05	0.00	0.0133	0.00					0.21
6 Water	0.00	0.00	0.00	0.00	0.00	0.00					0.00
7 Total Feed	56.10	16.47	18.76	9.54	3.84	2.01					106.71
8 Raffinate	16.51	18.81	9.52	3.85	2.01	1.99					52.70
9 Sampling	0.32	0.35	0.22	0.05	0.03	0.00					0.98
10 Spills	0.00	0.00	0.00	0.00	0.00	0.00					0.00
11 Residuals	0.00	2.04	0.03	0.04	0.01	0.00					2.13
12 Basket Strainer	1.48	0.52	0.27	0.53	0.16	0.05					3.01
13 (H2O)	0.00	0.00	0.00	0.00	0.00	0.00					0.00
14 Cartridge Filter	0.00	0.00	0.00	0.00	0.00	0.03					0.03
15 Extract	0.00	0.00	0.00	2.62	0.00	3.27					5.89
16 Spills	0.00	0.00	0.00	0.00	0.00	0.00					0.00
Output	18.31	21.72	10.04	7.10	2.21	5.35					64.73
Accumulation & Other Losses	37.79	-5.25	8.72	2.44	1.63	-3.34					41.99

APPENDIX B

MASS BALANCES FOR DECONTAMINATION EFFLUENTS

Mass Balance for Test 3 Fuel Wash

Test 3 Pass 1 09-17-88		Date	Raw Data	Corrected Data	Std Dev (lbs)	Analyte Data: PCB Conc. (ppm)	PCB Std Dev (ppm)	PCB Mass (g)	PCB Std Dev (g)
EPT-W1	Coleman Fuel (gal), est		1.00		0.0000				
	* Specific Gravity		0.72		0.0000				
	* Density of Water (lbs/gal)		8.35		0.0000				
	Wash Amount (lbs)		6.00		0.0293	560	95.2	2.12	0.05
EPT-W20	Coleman Fuel (gal), est		18.00		0.0077				
	* Specific Gravity		0.72		0.0000				
	* Density of Water (lbs/gal)		8.35		0.0000				
	Wash Amount (lbs)		108.07		0.5277	570	96.9	38.78	0.52
Still Bottoms	Residuals (gal), est		0.47		0.0015				
	* Specific Gravity		0.96		0.0000				
	* Density of Water (lbs/gal)		8.35		0.0000				
	Wash Amount (lbs)		3.75		0.3125	3400	578	8.03	0.86
Totals	EPT-W1		6.00		0.0293			2.12	0.05
	EPT-W20		108.07		0.5277			38.78	0.52
	Still Bottoms		3.75		0.3125			8.03	0.86
	Total Output (lbs)		117.82		0.9325			48.93	1.20

Analyte Data

Mass Balance for Test 5, Toluene Wash

Test 5 Passes 1-3 10-2-88		Date	Raw Data	Corrected (lbs)	Variance (lbs)^2	PCB Conc. (ppm)	PCB Variance (ppm)^2	PCB Mass (g)	PCB Variance (g)^2
Feed	Toluene Feed (gal), est		100.00	100.00	2.08				
	* Specific Gravity		0.87	0.87	0.00				
	* Density of Water (lbs/gal)		8.35	8.35	0.00				
	Net Feed		723.11	723.11	145.25	0.00	0.00	0.00	0.00
RPT	Toluene Wash + Drum	10/5	226.00	226.00	0.00				
	- Drum	9/29	38.50	38.50	0.00				
	Toluene Wash		187.50	187.50	0.00	185.00	989.10	18.16	7.17
	Toluene Wash		187.50	187.50	0.00			18.16	0.00
	+ Sample Losses		0.52	0.52	0.00			0.05	0.00
	Total Toluene Wash		188.02	188.02	0.00			18.21	0.00
RPT2	Toluene Wash + Drum	10/5	74.00	74.00	0.00				
	- Drum	9/29	38.75	38.75	0.00				
	Toluene Wash		35.25	35.25	0.00	34.00	33.41	0.63	0.01
	Toluene Wash		35.25	35.25	0.00			0.63	0.01
	+ Sample Losses		0.52	0.52	0.00			0.01	0.04
	Total Toluene Wash		35.77	35.77	0.00			0.64	0.04
EPT	Toluene Wash + Drum A	10/5	323.50	323.50	0.00				
	- Drum A	9/29	39.50	39.50	0.00				
	Toluene Wash		284.00	284.00	0.00	842.50	20513.40	125.26	341.02

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